METALLURGIA

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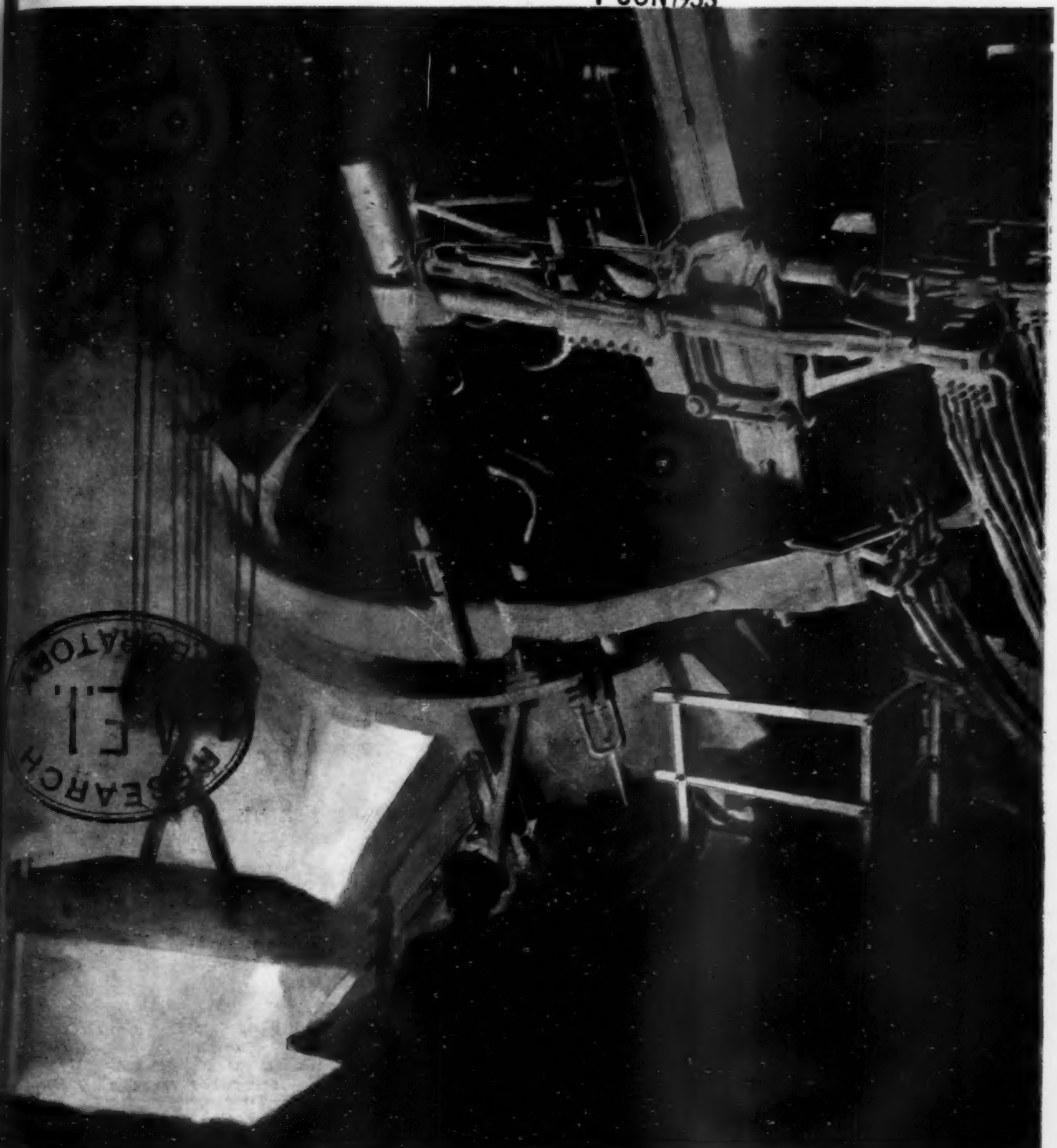

alloy steel from an electric arc furnace at Panteg

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CONTENTS FOR MAY, 1953

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

MAY, 1953 Vol. XLVII. No. 283

Casting Co-operation

WHEN the term "industrial relations" is used—and it is used a good deal these days—it is usually taken to refer to the attitude to one another of employers and employees, as it is affected by such factors as wages, conditions of work, and so on. Another aspect of industrial relations was spot-lighted in London last month, however, and one which is no less important, particularly from the technical point of view. We refer to the Customer/Founder Convention organised by the British Steel Founders' Association. The steel foundry industry was the first to send a productivity team to study the methods in use in their industry in the United States, and the report prepared by the team has served as a pattern for subsequent visiting teams representing other industries. In the Convention just held, they have blazed the trail once again, for there are many other industries concerned with tailor-made rather than off-the-peg products, where a get-together of customer and supplier would be of mutual benefit.

In opening the Convention, the Minister of Works, the Rt. Hon. David Eccles, said he understood that its purpose was to show the customer the mysteries of the production of steel castings, which he felt was an excellent idea because, with increasing specialisation, one of the most pressing needs on the industrial front to-day was to find better ways by which the experts in the different branches could communicate with one another.

Mr. T. H. Summerson, Chairman of the B.S.F.A., said that so far as they knew, no industry in any country had previously sought, through such means, to arrive at a complete understanding with all its customers. Besides letting the customers know the steps being taken to give them better products and a better service, the Convention would provide them with an opportunity of telling the industry in what respects its products were not all that they should be, and how, in their opinion, they could receive better service in the future. The steelfounders did not expect a clean bill of health but they looked forward to hearing in plain terms the opinions and advice of users of steel castings.

The fact that something can be drawn is no assurance that it can be made—it may defy the laws of nature. An example of this occurred some years ago when customer-manufacturer relations were strained because, in drawing a brazed joint, the draughtsman indicated the presence of the brazing metal by means of a fillet of such generous dimensions as considerations of surface tension would not allow of achievement in practice. For the steelfounders it was pointed out that there are three important factors, dependent on the fundamental and unalterable behaviour of steel, which limit what can be achieved in the way of difficult steel castings. These factors are the 11% shrinkage and contraction from molten steel in the ladle to the final cold casting; the low strength and ductility of cast steel at temperatures immediately below the freezing point; and the high melting point, which makes it difficult to find mould materials which have the requisite mechanical properties but will not "burn-on."

The basic fundamental necessities to secure a sound casting are well known to steelfounders and their technical and metallurgical staffs, but, in many cases, designers expect a higher degree of freedom from defects than they have a right to expect from the designs they put out. Steelfounders would be greatly helped if designers regarded as a necessity the need for them to understand why shrinkage spots, hot tears, and sand inclusions occurred in steel castings they had designed. As service conditions increase in severity, the standards of soundness and the severity of inspection will rise, and it is more than ever necessary that more than lip service be paid to the ideal of co-operation between designer and founder. To that end it was suggested that designers of castings should spend a few days, or a few weeks, with a steel foundry making a speciality of those castings in which they are interested.

Steel castings are seldom entirely free from defects, but the defects are frequently of a minor nature and of little significance. It is important, therefore, that the standards of acceptance should be agreed at the time of placing the order, so that it can be decided whether a casting of the standard required is possible at an economic price. Frequently the founder hesitates to put forward what he really needs, both in time and cost, if the designer's requirements are to be met in full, lest the order should go elsewhere.

On the question of soundness, it was emphasised that, whereas for purely mechanical applications there may be room for concessions, seldom is this the case with castings such as turbine casings which are to be used for pressure vessels, whose functions are related virtually to the entire casting.

An important step taken by one engineering firm in an effort to improve casting quality and to reduce time lost due to faulty castings, was described to the Convention. This is the formation of a "Steel Castings Rectification Committee" composed of manufacturing superintendent (chairman), steam turbine engineer, metallurgist, chief draughtsman, chief pattern maker, purchasing agent and—by invitation from time to time—a steel foundry manager. Such a procedure is not only valuable in deciding the action to be taken on current defects and difficulties, but it also results in each member of the committee improving his knowledge of those aspects of the subject outside his own specialised interests. This in turn should lead to better designs, from the founder's point of view, and so to improved castings with fewer defects. Without doubt, co-operation is the keynote to the achievement of that better service which founder and customer alike appreciate will be to the benefit of both.

B.W.R.A. Summer School

THE School of Welding organised by the British Welding Research Association is rapidly becoming a well-known event in the industrial calendar. This year, the emphasis was placed on the need of welding for increased productivity and economy in the major industries of the country. The School was held, as in previous years, at Ashorne Hill, near Leamington Spa, from April 27th, 1953, to May 2nd, 1953, and was attended by 160 students. Each student attended one of five groups of lectures representing the aircraft, shipbuilding, car and sheet metal, structural engineering and general engineering industries. During the week, each group attended 19 lectures, some of the lectures being common to all students.

As on previous occasions, a book containing summaries and illustrations of general interest for all the lectures for each group was handed to students on arrival, and other relevant material was handed out at individual lectures. Forty-five lecturers and others who took part in the school programme were present during the week, and on two evenings discussion groups were arranged, one being in the form of a brains trust, with Mr. John Thompson, of John Thompson, Ltd., in the chair, and Mr. E. J. Hill, General Secretary of the United Society of Boilermakers, Shipbuilders and Structural Workers, as one of the participants, to mention only two of the very distinguished team assembled.

An exhibition showing major all-welded components pertinent to the various industrial groups was shown at the school, and these components, combined with many illustrations, models, etc., provided a background for subsequent discussion for the students and were appreciated by all concerned. The exhibition included spot-welded motor car chassis and body parts, an aircraft petrol tank and jet nozzle case, an aluminium bedplate for a marine engine, a unit construction bridge panel, and a base for a mobile crane.

On two evenings film shows were given, with a mixed bag of technical films which included a first screening of the new B.W.R.A. film on the construction by welding of the superstructure of the Thames Launch *Queen Elizabeth*, together with others of general interest such as the Shell Petroleum film on the 1952 Le Mans race. The School concluded on Saturday May 2nd, with a lecture by Dr. H. G. Taylor, Director of Research of the British Welding Research Association on "The Need for Welding Research."

International Magnesium Exposition

THE first U.S. all magnesium exhibition was open to the general public from March 31st to April 2nd and was attended by over 26,000 visitors. Two English firms, Magnesium Elektron, Ltd., and Essex Aero, Ltd., were represented with commodious stands so that, apart from the stimulus it gave to the magnesium industry in general, the exhibition also served to make known British progress in the magnesium field to American technicians, and to introduce American achievements to British experts. Moreover, since the M.E.L. stand contained specimens of the work of nearly all their licensees, including those on the continent of Europe, it represented to some extent the magnesium industry of Europe.

M.E.L. themselves featured a research exhibit of their new ZT1 alloy. On this stand particular interest was shown in the Ferguson tractor and its magnesium castings, in the ZT1 castings for Napier's, the Dowty Z5Z main undercarriage leg casting (both by Sterling Metals, Ltd.), and in the canopy of the D.H. Sea Venom made by J. Stone & Co., Ltd. Amonst other exhibits, Essex Aero, Ltd., featured the JX2 Allard with an all-magnesium body, a mobile and adjustable hospital bed, stackable chairs and crates for bottles, etc. Service chiefs and personnel were mainly interested in the aircraft fuel tanks, the ultra-light walkie-talkie box and the 40- and 80-watt wireless carriers. Magnesium forgings and castings also created a lot of interest.

American firms displayed an impressive array of cast and wrought applications. Of special interest were: an army ordnance trailer containing 4,600 lb. of magnesium (one casting alone weighed 1,630 lb.—said to be the largest magnesium casting in the world); a freight pod for attachment to the XC-120 Fairchild aircraft; the Northrop experimental aircraft built largely of magnesium; the cast aircraft wing for Northrop; the tail cone of the B-47 aircraft; powder extrusions by the Dow Chemical Company; the Douglas Sky Rocket aircraft which has flown at a record speed of 1,237 miles per hour, most of the fuselage of which is made of magnesium alloy sheet; a fabricated wing for a fighter aircraft; a sheave in Z5Z alloy to replace the cast steel sheaves used in catapult launching gear for aircraft; a large all-magnesium truck body and a comprehensive selection of ladders. In addition there was the usual wide range of dockboards, trucks, roller conveyors, textile accessories, etc A practical demonstration of the new H.A.E. surface treatment process was given, whilst on the stand of the Magnesium Association hot pressing, welding, tube bending and impact extruding were being shown.

In the course of the opening ceremony, which was attended by officials of the U.S. Government and armed forces, it was stated that the annual consumption of magnesium in the U.S.A. might be expected to reach 120,000 short tons by 1960 (compared with about 50,000 short tons now).

Magnetism Lecture

THE first of a new series of lectures inaugurated by the Permanent Magnet Association was delivered on April 22nd last by Professor W. Sucksmith F.Inst.P., F.R.S., in Sheffield before a distinguished audience of some 200 people representing the metallurgical and electrical industries. He traced the remarkable developments that have taken place in the theory of magnetism and its practical applications during the last fifty years. Starting from the classical work of Ewing and Weiss he touched on the developments up to the 1930's and then spoke of the parallel advances in theory and practice in the last 25 years. These he said had resulted in a 40-fold increase in energy of permanent magnets and a thousand-fold increase in the permeability of soft magnetic materials. The lecture is to be published in full in the *British Journal of Applied Physics*.

Mr. Spencer Levick, the Chairman of the Association, presided over a dinner which followed the lecture and he and others paid tribute to the team spirit pervading the Permanent Magnet Association. Not only did it perform the functions of a Trade Association, but it also owned its own Central Research Laboratories and maintained an information service.

Embrittlement of Low-Phosphorus Phosphorus "Deoxidised" Coppers*

By B. T. Houlden†, A.R.S.M., B.Sc., Ph.D., D.I.C. and
W. A. Baker‡, B.Sc., F.I.M.
(Communication from The British Non-Ferrous Metals Research Association)

When molten copper containing oxygen is deoxidised with phosphorus, cuprous phosphate deoxidation products are formed and in practice some inclusions of such phosphates appear in the cast copper. When the residual phosphorus content is low, of the order 0·01 per cent. or less, the inclusions break down, to yield copper, cupric phosphate(s) and cuprous oxide as the copper cools, and when the copper is annealed in hydrogen, or in atmospheres contaminated with oil vapours, the cuprous oxide may react with hydrogen to form steam and thereby cause embrittlement of the copper.

SOME years ago manufacturers occasionally encountered room temperature embrittlement of phosphorus "deoxidised" coppers containing less than about 0·015% phosphorus. For example, fracture occurred in drawing thick-walled copper tubes in which the contents of known harmful impurities such as bismuth and lead were below the accepted tolerance levels. The question has therefore arisen whether such coppers are incompletely deoxidised and whether the cold embrittlement can be explained along these lines.

An earlier paper[1] describes an investigation of the equilibrium between oxygen and phosphorus in copper, partly because of its general interest in view of the widespread use of phosphorus as a deoxidant of copper and copper alloys, and partly with a view to throwing light on the above-mentioned difficulty. This work showed that the deoxidation products which form when phosphorus is added to a copper melt containing oxygen are essentially cuprous phosphates with variable proportions of cuprous oxide and phosphorus pentoxide. The deoxidation products form molten globules which rise out of the copper bath, but small amounts of oxygen remain in solution in the copper in equilibrium with the added excess of phosphorus. As the copper cools to its melting point the solubility of oxygen decreases, so that even if all the deoxidation product initially formed escapes from the melt before pouring commences, the cast material still contains small globules of deoxidation product, which have been rejected from solution as the copper cools to the melting point and freezes. The phosphorus contents of the deoxidation products are higher the higher the residual phosphorus content of the melt. Deoxidation products containing about 19% of phosphorus broke down, on cooling to temperatures of the order of 500° C. or lower, to yield metallic copper plus cupric phosphates, whereas deoxidation products of lower phosphorus content, e.g. 12%, broke down to yield copper plus cupric phosphates plus cuprous oxide. These low-phosphorus deoxidation products are present in cast coppers of low phosphorus content, and it seemed possible that the above-mentioned embrittlement might be due to the appearance of free cuprous oxide in the coppers and to resultant gassing during annealing.

The amounts of free cuprous oxide in low-phosphorus coppers are less than those present in normal tough pitch coppers and, since it is known[1] that the cuprous oxide content has a considerable influence on the behaviour of copper on annealing in reducing atmospheres, the present work also included tests on coppers of low oxygen content and free from phosphorus.

The embrittlement referred to earlier was encountered after annealing the low-phosphorus coppers in burnt-gas atmospheres, which were nominally slightly oxidising and which did not embrittle tough pitch material. These atmospheres consist essentially of nitrogen plus steam and carbon dioxide, but may include small amounts of sulphurous gases and also gases derived from drawing lubricants adhering to the metal. However, coppers are commonly annealed in steam atmospheres, which also do not embrittle tough pitch material and in the present work steam atmospheres, with and without additions of oil and other lubricant vapours, were used in most of the tests.

Embrittlement Tests

Two series of alloys were made. The first was a series of phosphorus deoxidised coppers with phosphorus contents increasing from 0% (tough pitch copper) up to about 0·1%. These materials were hot and cold worked to produce :—

(1) 18 s.w.g. × ½ in. wide strip, with a final 67% cold reduction, from which reverse bend test samples were machined with dimensions 18 s.w.g. × 1 in. × ⅜ in.

(2) 18 s.w.g. wire, with a final 99·7% cold reduction, which was used for both tensile and reverse bend tests.

The second series of alloys contained no phosphorus and had oxygen contents of 0·0017% to 0·084%. These materials were rolled to 18 s.w.g. strip for reverse bend tests as for the materials above. The preparation of the alloys and some details of the experimental technique adopted are described in detail in an appendix to the paper, where a few experimental results of interest, but not essential to the present account, are also included.

Tables I to III give the results of tensile and reverse bend tests on 18 s.w.g. wires of the coppers containing phosphorus, after annealing in nitrogen, hydrogen,

* B.N.F. Report R.R.A. 914P. The work described in this paper was made available to members of the B.N.F.M.R.A. in a confidential research report issued in August, 1951.
† Formerly Investigator, B.N.F.M.R.A.
‡ Research Manager, B.N.F.M.R.A.

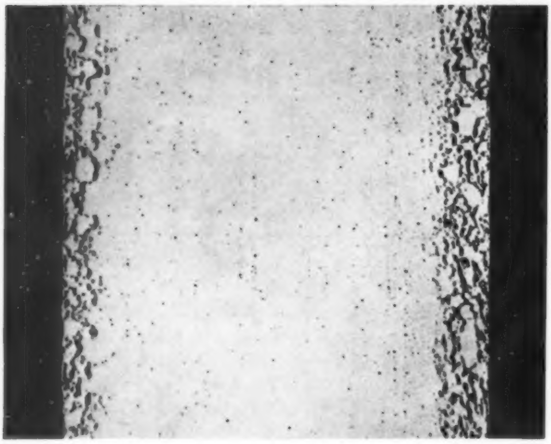

Fig. 1.—OTH. 0·066% oxygen. Unetched. Specimen annealed in steam plus oil at 600° C. broke after six reverse bends (see Table II). × 60

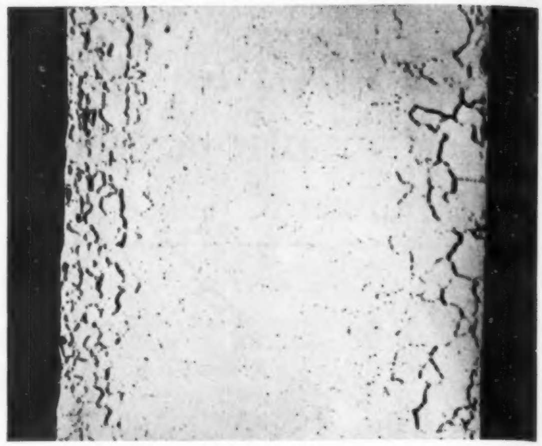

Fig. 2.—OTJ. 0·002% phosphorus, 0·027% oxygen. Unetched. Specimen annealed in steam plus oil at 600° C. broke after two reverse bends (see Table II). × 60

steam and steam plus lubricating oil atmospheres. Table IV gives the results of reverse bend tests on 18 s.w.g. strips of copper with various oxygen contents, some containing phosphorus also, after annealing in a steam plus lubricating oil vapour atmosphere.

The tensile tests were less discriminating than the bend tests, possibly because the elongation values were very variable, but the figures give an indication of the properties of the materials. The bend tests gave consistent results and, as for the tensile tests, the results reported are the means of triplicate observations. The wires and strips were bent, and reverse bent, through 90° round rollers 0·3 in. diameter.

The notable feature of the bend test results is that on annealing in hydrogen at 600° C. or 800° C. the embrittlement was more severe the higher the oxygen content of the metal irrespective of the phosphorus content, whereas when the materials were annealed in steam plus oil vapour, the coppers of low oxygen content, which also contained phosphorus, were usually the most seriously embrittled.

Micrographic examination of representative samples from these specimens explained the above features as follows :—

The wires and strips were all heavily cold worked before annealing in the various atmospheres, and in all cases they recrystallised during the treatments given. However, it was clear that in some cases marked crystal growth had also occurred, while in others crystal growth

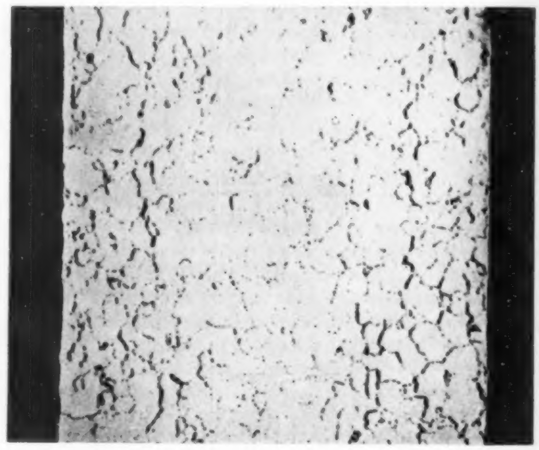

Fig. 3.—OTK. 0·007% phosphorus, 0·014% oxygen. Unetched. Specimen annealed in steam plus oil at 600° C. broke after one reverse bend (see Table II). × 60

had been arrested either by strings of cuprous oxide or by rapid development of intercrystalline voids, this latter condition being especially noticeable where the specimens had been annealed in hydrogen atmospheres. In these latter cases the intercrystalline porosity

TABLE I.
TENSILE TESTS ON ALLOYS ANNEALED AT 600° C. (18 S.W.G. WIRES).

B.N.F. Mark	P%	O%	Nitrogen Annealed		Hydrogen Annealed		Steam Annealed	
			U.T.S. tons/ sq. in.	El% on 2 in.	U.T.S. tons/ sq. in.	El% on 2 in.	U.T.S. tons/ sq. in.	El% on 2 in.
OTH ..	—	0·066	17·0	39½	10·2	7½	16·8	36½
OTJ ..	0·002	0·027	16·1	42	15·3	26	16·?	39
OTK ..	0·007	0·014	16·1	40	16·0	40	16·3	41½
OTL ..	0·009	0·0092	17·3	38	17·5	31	17·2	24½
OTM ..	0·015	0·0059	16·9	39	17·3	33	16·8	37½
OTN ..	0·018	0·0071	17·3	34½	17·6	35	17·3	46
OTO ..	0·023	0·0051	16·6	27½	16·3	27	15·8	39
OTP ..	0·038	0·0082	17·3	20	17·7	25½	17·1	38
OTR ..	0·096	0·0060	17·3	32	17·3	34	15·8	19½

TABLE II.—REVERSE BEND TESTS ON ALLOYS ANNEALED AT 600° C (18 S.W.G. WIRES).

B.N.F. Mark	P%	O%	No. of Reverse Bends before Rupture			
			Nitrogen Annealed	Hydrogen Annealed	Steam Annealed	Steam plus Oil Vapour Annealed
OTH ..	—	0·066	19	1	20	6
OTJ ..	0·002	0·027	22	2	24	2
OTK ..	0·007	0·014	25	10	21	1
OTL ..	0·009	0·0092	19	18	21	19
OTM ..	0·015	0·0059	21	20	21	19
OTN ..	0·018	0·0071	20	20	20	18
OTO ..	0·023	0·0051	22	22	20	19
OTP ..	0·038	0·0082	19	19	21	19
OTR ..	0·096	0·0060	20	20	20	17

TABLE III.—REVERSE BEND TESTS ON ALLOYS ANNEALED AT 800° C. (18 S.W.G. WIRES).

B.N.F. Mark	P%	O%	No. of Reverse Bends before Rupture			
			Nitrogen Annealed	Hydrogen Annealed	Steam Annealed	Steam plus Oil Vapour Annealed
OTH ..	—	0·066	18	<1	17	6
OTJ ..	0·002	0·027	21	1	13	2
OTK ..	0·007	0·014	23	1	21	1
OTL .	0·009	0·0092	18	20	17	17
OTM ..	0·015	0·0059	18	18	16	16
OTN ..	0·018	0·0071	17	16	15	17
OTO ..	0·023	0·0051	20	16	16	19
OTP ..	0·038	0·0082	19	18	13	18
OTR .	0·096	0·0060	16	16	14	16

TABLE IV.—REVERSE BEND TESTS ON ALLOYS ANNEALED IN STEAM PLUS OIL VAPOUR AT 800° C. (18 S.W.G. STRIPS).

B.N.F. Mark	P%	O%	No. of Reverse Bends before Rupture
OTJ	0·002	0·027	<1
OTK	0·007	0·0135	<1
OTL	0·009	0·0092	14
OTM	0·015	0·0059	15
Nov/279 ..	—	0·0018	17
Nov/280 ..	—	0·0073	16
Nov/290 ..	—	0·012	3
Nov/291 ..	—	0·017	4
Nov/292 ..	—	0·021	3
Nov/296 ..	—	0·031	3
Nov/287 ..	—	0·035	2
Nov/284 ..	—	0·084	3

appeared as stringers of voids more or less parallel to the axis of the strips or wires, and the effect of such porosity on the ability of the material to withstand reverse bending was naturally less serious than in the other cases where crystals had grown to equiaxial shapes, and where the intergranular porosity did not have this directional characteristic. In addition to these features, the depth below the wire or strip surface

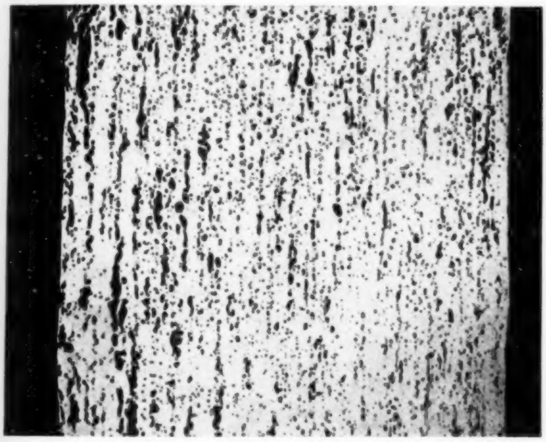

Fig. 4.—Nov/292. 0·021% oxygen. Unetched. Strip specimen annealed in steam plus oil at 800° C. broke after three reverse bends (see Table IV). × 60

to which the intergranular porosity had penetrated varied in some cases. In particular, with wires annealed in steam plus oil at 600° C. there were marked differences in this respect (see Figs. 1–3), which accounted in part for differences in the reverse bend values. From Table II it will be seen that in coppers OTH, OTJ and OTK, which have phosphorus contents increasing and oxygen contents decreasing in the order given, the embrittlement after this heat treatment was more severe the higher the phosphorus content of the metal, and the lower its oxygen content. Microscopic examination showed that the depth of penetration of intercrystalline porosity was greater the higher the phosphorus content and, moreover, in these three cases the porosity was less directional with respect to the axis of the wire the higher the phosphorus content. Both of these characteristics no doubt contributed to the fact that the wires of highest phosphorus content were the most seriously embrittled.

Of the coppers containing small amounts of oxygen but no phosphorus (Table IV) only those containing free cuprous oxide were embrittled by annealing in steam plus oil vapour and in these the embrittlement was much the same for all oxygen contents. Micro-examination showed that the intergranular porosity was in all cases strongly directional, and this feature presumably accounts for the fact that the embrittlement was rather less severe than in the low-phosphorus coppers (*cf.* Figs. 4, 5 and 6).

To summarise these observations, it would appear that, when the atmosphere contains a large proportion

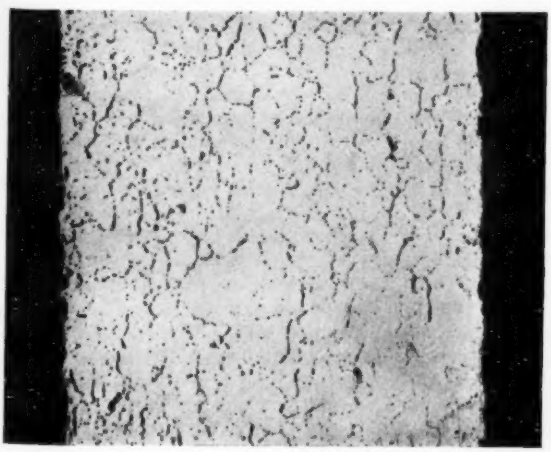

Fig. 5.—OTJ. 0·002% phosphorus, 0·027% oxygen. Unetched. Strip specimen annealed in steam plus oil at 800° C. broke after less than one reverse bend. × 60

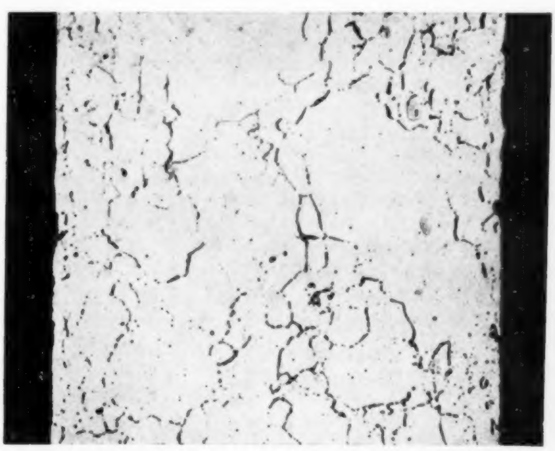

Fig. 6.—OTK. 0·007% phosphorus, 0·014% oxygen. Unetched. Strip specimen annealed in steam plus oil at 800° C. broke after less than one reverse bend. × 60

of hydrogen, intercrystalline porosity is rapidly formed as a result of the diffusion of hydrogen into the metal and, because the pores appear at the grain boundaries of crystals elongated by cold working, the porosity has a marked directionality with respect to the axis of the wire, and its harmful effect on the reverse bend properties of the wire is thereby mitigated. In these cases, the hydrogen eventually penetrates the wires completely, and the degree of porosity, and consequently the embrittlement, is greater the higher the oxygen content of the metal. On the other hand, when the amount of hydrogen in the annealing atmosphere is small, notably when annealing in steam plus oil vapour, recrystallisation and grain growth are in a more advanced state when "gassing" occurs, with the result that the voids resulting from the "gassing reaction" are distributed in a more harmful way. This grain growth is more marked the higher the phosphorus content of the metal within the range of compositions in question. Moreover, the depth to which the hydrogen penetrates in a given time is a function of the cuprous oxide content of the metal under such annealing conditions, and, in particular, coppers containing a little phosphorus, and consequently containing relatively little cuprous oxide, tend to be embrittled to a greater depth than tough pitch coppers.

For these reasons, coppers imperfectly deoxidised with phosphorus, which contain small amounts of cuprous oxide, may be more severely embrittled by "gassing" than tough pitch coppers, on annealing in certain atmospheres.

Breakdown of Cuprous Phosphates on Cooling

In view of the foregoing findings, it was of considerable interest to study the behaviour of the cuprous phosphate slags on cooling, with particular reference to the slag compositions which yield cuprous oxide on cooling.

The earlier work on the equilibrium between oxygen and phosphorus in molten coppers had established a relationship between the phosphorus contents of molten coppers and the compositions of the cuprous phosphates which would appear in the solid coppers. From this information it was possible to select a range of slag compositions appropriate for the present study.

Accordingly, seven cuprous phosphate slags, whose analyses are given in Table V, were heated to 1,000° C. in small alumina crucibles under an atmosphere of commercial "oxygen-free" nitrogen contained in a closed silica tube. At this temperature each of the slags was homogeneous and fluid, and after being held at 1,000° C. for 15 minutes the furnace was switched off and the assembly was allowed to cool within the furnace. The temperature fell to 500° C. in one hour and to room temperature in about four hours.

The resulting slags were examined microscopically. It was found that the slags containing 15·8% or less of phosphorus had precipitated cuprous oxide (see Figs. 7 and 8) and this was confirmed by X-ray examination of powdered samples of the slags.

TABLE V.—ANALYSES OF SLOWLY COOLED SLAGS

B.N.F. Mark	Cu%	P%	Al_2O_3%
Nov/77	$\sim$62	$\sim$12	$\sim$1
Nov/197/A	56·2	14·7	1·86
Nov/250	$\sim$57	$\sim$15	1
Nov/251	$\sim$56	$\sim$15·5	1
Nov/248	54·8	15·8	0·93
Nov/247	$\sim$53	$\sim$16·5	$\sim$1
Nov/198/A	51·2	16·9	2·98

Discussion and Conclusions

From the earlier study of the equilibrium between oxygen and phosphorus in molten copper[1], a copper melt containing 0·006% phosphorus is in equilibrium at 1,200° C. with a slag containing about 16% phosphorus and the present observations show that slags with this or lower phosphorus contents break down on cooling to yield some free cuprous oxide. Thus the present coppers containing 0·006% phosphorus or less would be expected to contain free cuprous oxide when cold and, as already noted, cuprous oxide was in fact detected in these materials. The embrittlement of these materials on annealing in hydrogen at 600° C. or 800° C. calls for no further comment because the gassing of coppers containing free cuprous oxide is a familiar phenomenon.

It remains to discuss the experimental observation that the coppers of low phosphorus content are more severely embrittled by "gassing" than tough pitch coppers under certain annealing conditions. Review of the literature on the embrittlement of coppers shows that phosphorus deoxidised coppers have only been briefly mentioned[3, 4] and in these cases the residual phosphorus contents have been high enough to exclude the formation of free cuprous oxide in the solid materials. The data concerning tough pitch coppers are, however, more plentiful[2, 5, 6, 7, 8]. Ransley[2] has explained clearly how the extent of "gassing" of coppers containing oxygen is influenced by the annealing conditions. Embrittlement does not occur so long as the diffusion of oxygen from within the metal to the metal surface can keep pace with the supply of hydrogen to the surface, i.e., so long as steam formed in the reaction is not liberated within the metal. Thus, when a copper containing free cuprous oxide is annealed in an atmosphere containing hydrogen, no gassing occurs until the free cuprous oxide near to the surface of the metal has been used up, i.e., has dissolved in the metal and diffused to the surface to react with hydrogen. After a time, however, when the cuprous oxide inclusions near the metal surface have been consumed in this way, the rate of diffusion of oxygen outwards cannot keep pace with the supply of hydrogen to the metal surface, and beyond this point hydrogen penetrates the metal and steam is liberated inside the metal, causing the familiar "gassing" embrittlement. Thus, for a given temperature of annealing and a given external pressure of hydrogen, the onset of embrittlement will be later the higher the oxygen content of the copper and, if the process is arrested before all of the oxygen is consumed in the reaction, the depth of the embrittlement will be less the higher the oxygen content. Ransley also shows that the mechanism involved depends to some extent upon the temperature of the anneal. At 600° C. and below, diffusion is largely confined to the grain boundaries, but at higher temperatures, diffusion through the body of the crystals contributes significantly to the reaction.

Some features of the present results are explained along precisely the same lines. In particular, the variations in depth of embrittlement in certain of the coppers can be explained in this way. However, in the present experiments, the issue is further complicated by the fact that the specimens were recrystallising and the new crystals were growing during the annealing treatment. It appears that, in the materials now examined, the rate of crystal growth was greater in coppers containing phosphorus than in material free from this

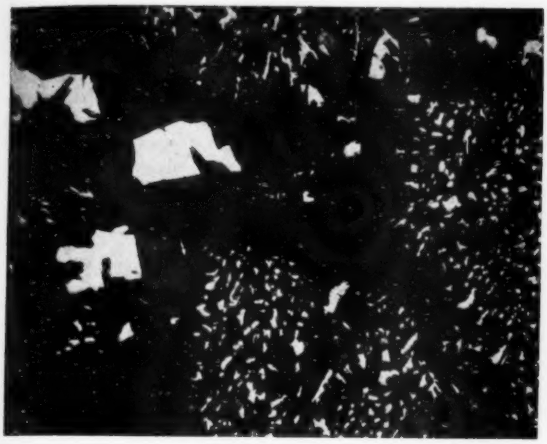

Fig. 7.—Nov/197/A. 14·7% phosphorous slag after slow furnace cooling from 1,000° C. Unetched. Specimen shows copper particles (white), cuprous oxide (pale grey) and two unidentified phases (dark grey and black) × 400

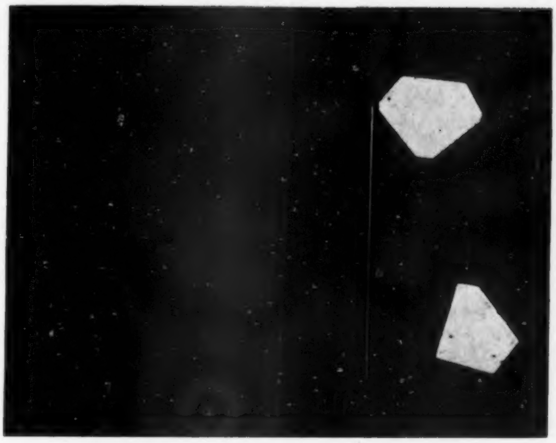

Fig. 8.—Nov/198/A. 16·9% phosphorus slag after slow furnace cooling from 1,000° C. Unetched. Specimen shows large copper crystals and fine particles (white) in a glassy matrix. × 400

element, with the result that when coppers containing phosphorus, together with some free cuprous oxide, were annealed in atmospheres containing little hydrogen, the intercrystalline voids were distributed in a particularly harmful way. It is clear, however, that the conditions of annealing likely to cause such damage of these coppers are critical and this may account for the fact that the trouble has rarely been experienced in practice.

On the few occasions when embrittlement was encountered in practice, it occurred in coppers containing less than 0·015% phosphorus, whereas in the present tests only coppers containing 0·007% phosphorus or less were especially liable to the embrittlement described. Several factors could contribute to this discrepancy, if in fact the embrittlement was due to the same cause in both cases. Firstly, it has been shown[1] that the co-solubility of phosphorus and oxygen in molten copper increases markedly with temperature and it can be shown that, for a copper melt poured from 1,250° C., i.e., 50° C. higher than in the present work, free cuprous oxide would appear in materials containing 0·008% phosphorus or less. Secondly, if the deoxidation procedure is such that some of the deoxidation products formed when phosphorus is added to the melt remain mechanically entangled in the melt when the latter is cast, cuprous oxide will appear in solid coppers with still higher phosphorus content. These two factors may well account for the discrepancy referred to above.

Embrittlement of the type described may be difficult to avoid in practice, because it is evident that small amounts of hydrogen or hydrocarbons may produce the effect (see, e.g., Section C of the Appendix). A possible remedy is to reduce the oxygen content of the melt still further before casting, by carrying out the phosphorus deoxidation under charcoal. It has been shown[1] that the oxygen content of phosphorus deoxidised melts can be reduced to a very low value if the deoxidation is carried out under a deep cover of charcoal, and if a period of 10 to 15 minutes is allowed for interaction between this cover and the melt. In the laboratory experiments it was possible to reduce the oxygen content in this way to a very small order (about 0·0005%), and if this could be done on a larger scale, it is reasonable to expect that low-phosphorus coppers could be made immune from the kind of embrittlement discussed above. However, copper rapidly absorbs oxygen during pouring through air and, to take advantage of this deoxidation with carbon, it would be necessary to envelop the metal stream in an inert or reducing atmosphere during pouring, and special equipment would be necessary for this purpose.

Acknowledgments

The authors are indebted to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper.

APPENDIX

A.—Preparation of the Materials

(a) The Varying Phosphorus Series of Alloys.

Nine alloys were made with various oxygen and phosphorus contents, the latter varying from nil to about 0·1%. In each case a charge of 10 lb. of cathode copper was melted in a small tilting high frequency furnace, using a Salamander crucible lined with Alundum cement and fitted with a lid through which a stream of "oxygen-free" nitrogen was introduced. Under this nitrogen cover the metal was raised to a temperature of 1,200° C. and a copper-oxygen alloy was added to give an oxygen content of about 0·03%. After a period of 3 minutes, copper-phosphorus (15%) alloy was added in the amount necessary to give one of various desired residual phosphorus contents, and after a further 5 minutes, sufficient to allow practically all of the deoxidation product to separate from these small melts[1] the metal was poured into a cast iron chill mould to give a casting of about 10 in. in length and 2 in. in diameter.

Control of the oxygen content before deoxidation was found to be difficult, owing to the diffusion of oxygen through the walls of the pot, and with three of the alloys (OTL, OTM and OTO) a charcoal cover was kept over the metal in addition to the nitrogen atmosphere.

Each casting was machined to 1¾ in. diameter by about 8 in. in length, preheated to 850°–900° C. for two

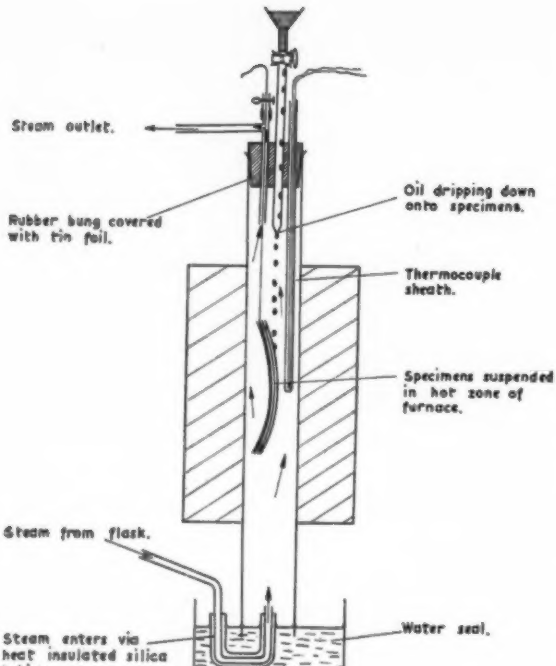

Fig. 9.—Apparatus for annealing in steam plus oil vapour.

hours and then hot rolled to $\frac{13}{16}$ in. square. This was followed by cold rolling and drawing to 18 s.w.g. wire, no intermediate annealing being used.

(*b*) *The Varying Oxygen Series of Alloys.*

These alloys were also made by two slightly differing methods. In both cases cathode copper was melted in a gas-fired furnace under a cover of charcoal and the metal was raised to a temperature of 1,250° C. followed by de-gassing by bubbling "oxygen-free" nitrogen through the metal for 5 minutes.

The first method of increasing the oxygen content of the castings was to allow intervals of about $\frac{1}{2}$ minute between successive castings during which time oxygen pick-up occurred. Alloys Nov/279, Nov/280, Nov/287 and Nov/284 were made by this method, Nov/279 being poured through a gas flame immediately after de-gassing and the others following in order after removal of part of the charcoal cover.

The second method was to make additions of copper-oxygen hardener to the metal followed by casting in a 1-in. diameter mould and then returning the metal remaining in the crucible to the furnace, for a further period of deoxidation under charcoal and nitrogen de-gassing before adding oxygen in suitable amounts for further castings. Alloys Nov/290, Nov/291, Nov/292 and Nov/296 were cast by this method.

The castings in either case were then machined to $\frac{3}{4}$ in. diameter and hot rolled in grooved rolls down to approximately 0·68 in. square. They were then annealed and cold rolled to a 0·47 in. × 0·38 in. section. Samples of the alloys OTJ, OTK, OTL and OTM were also cold rolled to this section, and all the bars were given a 1-hour anneal in "oxygen-free" nitrogen at 600° C. After this treatment smooth flat finishing rolls were used to reduce the metal to 18 s.w.g. strip.

B.—Apparatus for Annealing in Steam Plus Oil Vapour

The apparatus used is shown in Fig. 9. In each case the specimens were dipped into the oil and then suspended in the furnace. The furnace was flushed out with steam and was raised to the desired temperature, the oil being dripped onto the specimens during the whole of the experiment. After half an hour at temperature the specimens were quenched by dropping into the water seal below.

C.—Further Experimental Results

In some earlier trials on the effect of steam anneals on the wire specimens, occasional embrittlement was detected with alloys OTJ and OTK, giving material which would break after 11 and 5 reverse bends respectively. These inconsistencies were traced to hydrocarbons liberated by new rubber tubing carrying the steam to the apparatus, and they were eliminated by cutting down the rubber tubing to a minimum and by covering the bungs at the ends of the furnace with tinfoil.

Table VI summarises the results of embrittlement tests on wire specimens annealed in steam plus various oil vapours at 600° C. for half an hour. The oil used in the previous tests reported in Tables II and IV was a medium lubricating oil (C.Y.2) while a cutting oil was used for the treatment reported in Table III.

These alloy wires were also subjected to a nitrogen plus oil anneal at 600° C., embrittlement occurring as before, thus proving that the steam atmosphere is not a necessary component in the reaction. A methane anneal for $\frac{1}{2}$ hour at 600° C. failed to cause any embrittlement on any of the wires, thus demonstrating that relatively stable hydrocarbons do not cause embrittlement.

Table VII summarises the results of steam plus oil embrittlement torsion tests using specimens of $\frac{3}{16}$ in. diameter with a gauge length of $1\frac{1}{2}$ in. For comparison, the number of twists before failure for specimens annealed in nitrogen is also included. "Gassing" was in no case complete throughout the width of the specimens, but after $\frac{1}{2}$ hour in steam plus oil at 800° C. the relative depths of embrittlement in OTH, OTJ and OTK were $\frac{1}{15}$th, $\frac{1}{3}$rd and $\frac{2}{3}$rd of the radius respectively.

TABLE VI.—REVERSE BEND TESTS ON ALLOYS ANNEALED IN STEAM PLUS OIL VAPOUR AT 600° C. (using (*a*) cutting oil, (*b*) soluble oil, (*c*) a medium drawing lubricant).

B.N.F. Mark	P%	O%	No. of Reverse Bends before Rupture (*a*)	(*b*)	(*c*)
OTH	—	0·066	16	9	10
OTJ	0·002	0·027	11	5	9
OTK	0·007	0·014	14	6	10
OTL	0·009	0·0092	21	21	20
OTM	0·015	0·0059	20	19	20
OTN	0·018	0·0071	18	19	20
OTO	0·023	0·0051	22	22	20
OTP	0·038	0·0082	20	21	19
OTR	0·096	0·0060	20	21	22

TABLE VII.—TORSION TESTS ON $\frac{3}{16}$ IN. DIAMETER SPECIMENS.

B.N.F. Mark	P%	O%	600° C. Anneals			$\frac{1}{2}$ hr. at 800° C. Steam plus Oil
			$\frac{1}{2}$ hr. Nitrogen	$\frac{1}{2}$ hr. Steam plus Oil	4 hrs. Steam plus Oil	
OTH ..	—	0·066	$14\frac{1}{4}$	$9\frac{1}{2}$	8	$6\frac{3}{4}$
OTJ ..	0·002	0·027	$19\frac{1}{2}$	$14\frac{1}{2}$	11	$6\frac{1}{4}$
OTK ..	0·007	0·014	20	$16\frac{3}{4}$	—	$4\frac{3}{4}$
OTL ..	0·009	0·0092	$28\frac{1}{4}$	$25\frac{1}{2}$	22	21
OTM ..	0·015	0·0059	30	26	27	$21\frac{1}{4}$

As in the cases described in the text of the report, the differences between the behaviour of the materials in the torsion tests were explained by differences in the depth and distribution of the intergranular porosity in embrittled specimens.

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Patents in the United States

Some Aspects of the 1953 Act

By S. T. Madeley

MUCH patent work has been done in the United States since a patent was granted on October 17th, 1809 to Jos. Walworth of New York. The patent was for melting metals, and that is all we know about it, as specifications were not published then, nor, indeed, until some fifty years later. According to the 1951 records, however, there were some 90 U.S. patents granted in the field of metals.

In considering the 1953 U.S. Patent Act—Public Law 593, that part of the new law which deals more particularly with the domestic affairs of the United States patent office—such as the Establishment of the Office, Board of Appeals, Classification of Patents, and so on—will be ignored. It may be mentioned in passing, however, that the charge of 25 cents for an uncertified printed copy of a patent specification compares very favourably with the charge which our own patent office makes for a similar British Specification.

In discussing specific provisions of the Act, it may be pointed out that Section 100 defines *invention* as invention or discovery and *process* as meaning process, art or method, and including a new use of a known process, machine, composition of matter, or material.

New and useful processes, machines, manufactures, compositions of matter, or new and useful improvements thereof are patentable according to Section 101, but it should be noted that more than mechanical skill must be involved in integrating separate parts.

Conditions of Patentability

Conditions for patentability, novelty and loss of novelty and patent rights are set out in Section 102, which is reproduced below in full ("this country" of course meaning the U.S.A.).

"A person shall be entitled to a patent unless

(*a*) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the Applicant for patent, or

(*b*) the invention was patented or described in a printed publication in this or a foreign country, or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States or

(*c*) he has abandoned the invention, or

(*d*) the invention was first patented or caused to be patented by the applicant or his legal representatives or assigns in a foreign country prior to the date of the application for patent in this country or an application filed more than twelve months before the filing of the application in the United States, or

(*e*) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or

(*f*) he did not himself invent the subject matter sought to be patented, or

(*g*) before the applicant's invention thereof the invention was made in this country by another who had not abandoned, suppressed, or concealed it. In determining priority of the invention there shall be considered not only the respective dates of conception and reduction to practice of the invention, but also the reasonable diligence of one who was first to conceive and last to reduce to practice from a time prior to conception by the other."

It would seem that a foreign patent issued on a foreign application lodged over a year before the corresponding U.S. filing date must not be allowed to issue before the U.S. filing date.

When the subject matter of an invention sought to be patented differs so little from the prior art that it would have been obvious at the time the invention was made to a person having ordinary skill in the art, then Section 103 says the invention is not patentable.

From Section 104 we learn that patent applications based on one coming from abroad can only claim as priority date that of the foreign application in question (Section 119).

The specification has of course to be sufficiently full, clear, concise and exact, according to Section 112, for any person skilled in the art to which it pertains, or with that which it is most nearly connected, to be able to make and use the invention, which must however be clearly claimed. However, one will now, in a claim for a combination, be able to claim "a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material or acts described in the specification and equivalents thereof." It should be remembered, however, that claims over twenty in number will have to be paid for at the rate of a dollar a claim.

Joint Inventors

It may happen that a joint inventor refuses to join in an application for a patent, or cannot be found or reached after diligent effort, or that, without any deceptive intention, by error a person is joined as inventor in an application or omitted therefrom. Section 116

allows the application to be proceeded with by the other inventor or to be amended, as the case may be.

In a case where an inventor refuses to execute an application for a patent or cannot be found or reached after diligent effort and he has assigned or agreed in writing to assign his invention to a person or a person who otherwise shows sufficiently proprietary interest in the matter, that person may, under Section 118, make application for a patent on behalf of and as agent for the inventor, on satisfying the Commissioner in this connection.

Section 119 deals with benefit of earlier filing date in a foreign country and right of priority. An application in the United States based on a foreign application and claiming the said foreign priority date must be filed in the U.S.A. within twelve months from the earliest date on which such foreign application was filed, and a certified copy of the original basic application, specification and drawings, must be filed before the patent is granted, or as required by the Commissioner. If it is not in the English language a translation may also be required.

Where an inventor files a later application based on an earlier one, under Section 120, and refers to the earlier one in the later one, the later one will have the same effect, as regards such invention, provided the later one is filed before the patenting or abandonment or termination of proceedings on the earlier one. Divisional applications required by the Commissioner come under Section 121. The divisional case takes the date of the parent case from which it is divided. Such parent and divisional application patents are not to be used as references against each other either by the Patent Office or the Courts, provided the divisional application is filed before the issuance of a patent on the parent application.

Six months is still the maximum period under Section 133 for responding to an official action, and it may be as little as thirty days if the Commissioner so decrees.

Interferences

The important question of interferences comes under Section 135. The priority of invention is to be determined by a board of patent interferences, and final adverse judgment to a patentee, if not appealed or reversed will constitute cancellation of the relevant claims. " A claim which is the same as or for the same or substantially the same subject matter as a claim for an issued patent may not be made in any application unless such a claim is made prior to one year from the date on which the patent was granted."

It is of importance that the Specification on which a priority date is claimed should be as full and complete as a U.S. Specification or the priority date may be lost. This has espectal significance where the said basic specification is a British Provisional Specification.

Ronay *v.* Hediger (No. 5762) is an interesting interference case reported in Vol. 38 of United States Court of Customs and Patents Appeals Reports (Oct. 1st, 1950 –Oct. 1st, 1951). The invention was made during the War and related to a hollow, spray-coated ceramic electrode, for use with heating apparatus, especially an electric arc torch designed for underwater cutting in the hull of a ship. Ronay was given priority. Originality of invention, oath and supplemental oath, abandonment and reduction to practice were discussed.

An Applicant may, under Section 255, correct his mistake if of a clerical, typographical or minor nature and made in good faith. In the case where a joint inventor is included or omitted in error without deceptive intent in an issued patent, the error can be corrected under Section 256.

Section 271 relates to infringement of patent by whoever within the United States without authority makes, uses or sells a patented invention, and includes as liable those who induce infringement or contribute thereto.

Section 282 states that a patent is to be presumed as valid, and sets out briefly amongst the defences, non-infringement, absence of liability for infringement, unenforceability or invalidity of the patent.

A.D.A. Annual General Meeting

THE Annual General Meeting of The Aluminium Development Association was held at 33, Grosvenor Street, London, W.1., on Friday, 10th April, 1953, with the retiring President, MR. H. G. HERRINGTON in the Chair. Introducing the Report for 1952, he noted the continuing progress of the Association as shown, for example, by statistics of enquiries answered (2,750), publications distributed (132,000) and film shows given (over 400) and also by short and long-term development and research investigations pursued during the year, particularly in structural engineering, naval architecture large riveted joints, welding and finishing. Close co-operation continued with many Government Departments, other research, development and technical organisations, the B.S.I., professional institutions and learned societies.

The year 1952 had opened uncertainly owing to supply difficulties, but at its close there was fabricating capacity available, and this change had some effect on the Association's programme. There was likely to be more competition in the future, but the A.D.A. would be regarded as a spear-head of the Aluminium Industry's competitive efforts.

MR. R. D. HAMER, Vice-President and Director of Aluminium Laboratories, Ltd., was elected President for the ensuing year. After early schooling in England, Mr. Hamer attended University in Canada, graduating with the degree of B.Sc., followed by two years post-graduate studies in Berlin. He became interested in journalism and travelled extensively in Europe, served on the Technical Committee for the 1936 Olympic Games, and finally joined the Aluminium Company of Canada, Ltd., as a chemical engineer. After experience in several departments of the company, he took an active part in the war-time construction of the expanding aluminium industry in Canada, including the Shipshaw power development. In 1945 he joined Aluminium Laboratories, Ltd., the technical management company of the Aluminium, Ltd., group, of which Northern Aluminium Co., Ltd., Aluminium Union, Ltd. and Stand, Ltd. are members, and became a Vice-President and a Director in 1950.

The new Vice-President of the Association is MR. H. G. HERRINGTON. MR. G. W. LACEY was re-elected Chairman of the Executive Committee of the Association.

The Institute of Fuel

DR. W. IDRIS JONES, Director General of Research to the National Coal Board, has been elected by the Council of The Institute of Fuel as President for the 1953–54 Session. He will succeed the retiring President, Dr. G. E. Foxwell, in October of this year.

Metal Casting Methods

II—Centrifugal Casting

By J. B. McIntyre, M.Sc., A.I.M.

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The casting techniques most nearly approaching the ideal are the centrifugal and the continuous methods. In this second article of the series, the author considers the former process and discusses its application to horizontal and vertical axis machines. Reference is made to the production of pipes, cylinder liners, gear blanks and internally chilled hollow phosphor bronze sticks.

THERE are many methods in use for the production of cast material, though no ideal method exists which can be applied to all cases. Two processes approach the ideal requirements ; these are the centrifugal and the continuous casting processes respectively. The centrifugal casting technique may be used in the production of simple shapes such as discs and tubes, or for the production of sand castings of more intricate shape, whilst continuous casting is restricted to ingot and billet production and finds considerable application for that purpose, especially in the non-ferrous field. Both methods are of great economic value, in that they enable a greater tonnage of sound castings to be obtained from a given weight of molten metal than would be the case if ordinary casting methods were used. Additional and perhaps even more important features of these techniques are the improved soundness, uniform quality and comparative freedom from segregation which result from their use.

The centrifugal casting process is based upon the application of centrifugal force to assist feeding during solidification, and in certain cases to promote the separation of dissolved gases and other undesirable impurities such as slag. The application of this principle is quite old, and many patents have been recorded in this country and abroad. Shanks was granted a British patent in 1849 to cover the production of hollow cylindrical vessels without the use of cores. Eckhardt, in 1890, claimed "the use of moulds revolvable with their axes either horizontal, inclined or vertical, in order that centrifugal force due to the revolution may press the fluid metal against the interior surfaces of the mould, and more perfect castings thereby be produced." Bessemer is reported as having used a rotating mould in the course of his early experiments to produce sound steel from blown converter charges. The introduction of ferro-manganese as a deoxidising agent by Mushet solved the problem before centrifugal methods became established. Many other patents have been claimed during the past 100 years, though workers have restricted their claims, in the main, to new types of centrifugal machines, or methods of handling the liquid metal or the castings produced in the process.

Advantages of Centrifugal Casting

The essence of centrifugal casting was admirably stated by Eckhardt in his patent claim, and the virtues of the process may best be considered in relation to the static casting methods in more general use. When a simple hollow cylinder is cast in a static sand mould, the molten metal or alloy is comparatively slowly cooled ; dissolved gases and impurities tend to be rejected inward from the mould faces and to collect in the centre of the casting wall. This may also occur in the feeder head generally provided to combat the volume change taking place, when the metal or alloy changes from the liquid to solid state. The piped area in steel ingots is known to be generally richer in impurities than the surrounding material, and a similar feature can be expected in large steel castings produced in sand moulds when examined in the as cast condition. In contrast, a similar tubular casting produced by centrifugal methods freezes in a somewhat different manner. Each successive layer of metal applied to the mould sustains a pressure gradient across its radial thickness, the pressure being at its maximum in the outside layers and tending to decrease toward the inside. This gradient assists in the removal of gases and restricts the effect of liquid shrinkage to the inner surface of the cylinder.

It will be appreciated from the foregoing remarks that sound gas-free castings which show a high ratio of useful casting to liquid metal used, may readily be obtained when centrifugal methods are practised. The process is applied to both ferrous and non-ferrous alloys and, more rarely, to metals such as copper in the production of calico printing rollers. Centrifugal casting is usually regarded as an improved technique which can be applied to most castings in order to obtain the advantages already outlined. There are instances, however, in which centrifugal casting is the only possible production method. For example, when a limited number of highly alloyed steel tubes are required for chemical plant operating at elevated temperature and high pressure, such material frequently cannot be handled in the standard tube making equipment. Moreover, few mills can handle economically the limited quantity of such tubes which are usually needed.

The effect of cooling rate on soundness and grain size has already been discussed, and it should be noted that these effects are even more pronounced in centrifugally cast material. Tin bronzes, for example, exhibit considerable changes in microstructure when cast by various methods. The (α + δ) eutectoid which is a normal constituent of most industrially important tin bronzes may occur in several forms, depending upon the casting method used, and the physical properties are markedly affected by the size and distribution of the eutectoid. In the same way, the dispersion of insoluble elements, such as lead, is similarly influenced by cooling rate and casting method. Tin bronzes find wide

application where their resistance to abrasion and heavy loading is of value for bearings, worm wheels and so on. Sand cast material is not so efficient for such purposes as is the chill cast material and chill cast material is, in turn, less efficient than that cast in a rotating chill mould. Gear wheel blanks are subjected to extensive machining operations before use; the sounder and harder metal situated on the outer rim of each casting may be removed leaving, in sand cast material, somewhat inferior metal to form the gear teeth.

Horizontal Axis Casting

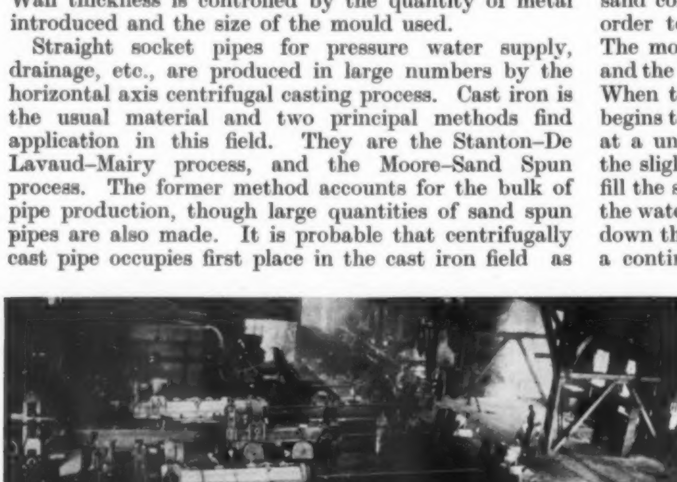
Centrifugal casting may be considered in two main sections—horizontal and vertical axis casting, respectively. Some inclined axis casting is also carried out, but this technique is not so widely used. The horizontal method is widely used in the production of castings having a tubular shape—water pipes, cylinder liners, piston ring pots, gun barrels and tubes for chemical plant being produced regularly on horizontal axis type machines; the greatest tonnage of centrifugal castings is produced on horizontal axis machines. When a quantity of liquid metal or alloy is introduced into a rotating horizontal mould, the metallic material is distributed over the inner surface of the cylinder due to the velocity of rotation, friction set up between the liquid metal and the mould material allowing the former to be distributed evenly. The inner surface of the casting assumes a cylindrical shape, and if the mould is rotated for a long enough period a tubular article is obtained. Wall thickness is controlled by the quantity of metal introduced and the size of the mould used.

Straight socket pipes for pressure water supply, drainage, etc., are produced in large numbers by the horizontal axis centrifugal casting process. Cast iron is the usual material and two principal methods find application in this field. They are the Stanton–De Lavaud–Mairy process, and the Moore–Sand Spun process. The former method accounts for the bulk of pipe production, though large quantities of sand spun pipes are also made. It is probable that centrifugally cast pipe occupies first place in the cast iron field as far as tonnage production is concerned. The processes are essentially similar, differing in details of mould construction and method used to introduce the metal supply. The sand spun method tends to be more flexible than the metal mould type, since flanges and so on may be incorporated in the pipe casting. This is not so readily done in the latter process, though pipes can be produced more rapidly in metal moulds than in the sand lined variety.

Metal Spun Pipes

The Stanton–DeLavaud–Mairy process utilises a revolving water-cooled steel mould which is accurately machined to provide the outer profile of the pipe casting. The steel mould is surrounded by a water-cooled container which is mounted on wheels, and is designed to traverse a steel track placed on a slightly inclined machine bed. Movement is controlled by a hydraulic cylinder mechanism.

Metal is supplied to the mould by means of a tilting hopper containing sufficient material to produce one pipe. The hopper is supported on a frame, which also carries a short launder or spout, enabling liquid metal to be transferred to a long cantilever pouring trough, and hence to the pipe mould. In the original De Lavaud system the pipes tended to be chilled to some extent, but the application of a thin layer of mixed ferro-silicon and plumbago to the mould before casting reduces the cooling rate to a suitable level. In this process, frequently described as the "metal spun method," a sand core is inserted in the socket end of the mould in order to produce the required internal socket shape. The mould container is moved to the top of the track and the mould is revolved by the electric motor provided. When the desired speed has been reached, the hopper begins to tilt, and the molten metal supply is transferred at a uniform rate into the rotating mould. Owing to the slight angle of inclination, the liquid metal tends to fill the socket portion of the pipe, and when this is done the water cooled mould assembly is withdrawn, travelling down the inclined track at constant speed. In this way a continuous spiral of liquid iron is deposited on the inner mould surface, eventually forming a continuous metal pipe. When the specified time of rotation has elapsed, internal grip tongs are inserted in the pipe, and the latter is withdrawn from the mould by moving the mould assembly up the track to the pouring station. The whole procedure may then be repeated and further pipes produced. A normalising process is usually applied to these pipes, involving heating to 880° C. for 45 minutes in a continuous gas-fired furnace. Finishing operations are restricted to an internal cleaning, followed by hydraulic testing and protective coating.



Courtesy of The Stanton Ironworks Co., Ltd.

Fig. 1.—The production of metal spun pipes.

Sand Spun Pipes

In the sand spun process, cast iron cylindrical moulding boxes are used. The boxes are placed on end and a cast iron pattern placed in each; adequate location is provided in the base of each box, and moulding sand rammed into the annular space left between the core and moulding box wall. Pneumatic rammers are used and, after the core has been removed, the rammed moulds

Fig. 2.—Microstructure of sand cast grey iron.

Courtesy of The Stanton Ironworks Co., Ltd.
Fig. 3.—Microstructure of centrifugally cast grey iron.

are air dried, then stove dried. Each dried mould is placed in a horizontal axis spinning machine and rotated at the required speed. Molten iron is poured into the mould by means of a comparatively simple device which need not be so involved as that used in the metal spun process. In the latter case, the liquid iron freezes rapidly when in contact with the metal mould and hence the cantilever pouring trough is essential if molten metal is to be evenly distributed over the mould interior. Sand-lined moulds on the other hand reduce the cooling rate of any casting considerably, and the molten iron is easily distributed. Pipes up to 24 in. outside diameter are produced by both the sand spun process and the metal spun method. Smaller sizes are more economically produced by the metal spun method, as an increased quantity of sand must be rammed into the average size moulding box in sand spun practice.

Some segregation is inevitable in centrifugally cast iron pipes. Sulphides and graphite tend to migrate toward the inner sections of the pipe, while iron-iron phosphide eutectic segregates toward the outside. It is likely that metal spun pipe will be less affected than sand spun pipe since the casting cycle and rotation time of the latter is much greater. Much will depend upon the mass of metal concerned, and such segregation is not serious in either product.

The sand spun process has been adapted to the production of gun barrels, hollow shafting, rolls, and similar products, where maximum density and consistent properties are necessary. Moore and McKay have described the production of such articles in alloy steels, little variation being seen from the technique used for the production of cast iron pipes, though details of mould material and metal casting temperature are naturally different.

The mould material used for cast iron pipes is a very coarse grade natural moulding sand, faced with a refractory wash, and the casting temperature is in the region of 1,250°–1,300° C. It is interesting to note that the ordinary moulding sand containing appreciable proportions of coal dust, which finds wide application in normal iron foundry practice, is not used in centrifugal practice. When such sands are used gas generated as the molten iron reaches the coal dust apparently causes a cushion effect. Frictional effects which normally allow the molten iron to attain the requisite mould speed are reduced to such low levels that slipping occurs and the required tubular shape is not then obtained. Centrifugal steel castings require a more refractory mould material, a mixture of silica sand, fireclay and silica flour bonded with water and bentonite being used. The recommended casting temperature is between 1,520° C. and 1,600° C., and it seems that a controlled pouring speed is necessary. An orifice varying from $1\frac{1}{2}$ in. to 3 in. diameter is recommended, depending upon the pipe diameter. The microstructure of centrifugally cast steel is similar to that obtained from a good sand casting, but the grain size is smaller and the physical properties obtained are superior to those found in statically cast material of similar analysis. A limited amount of carbon segregation is experienced in centrifugally cast steel; Dickson, Moore and McKay, and Northcott and McLean, have also reported such segregation. Since this occurs on the inner parts of the castings concerned, no appreciable ill-effects can be expected.

Cylinder Liners

An important part of the industry producing centrifugal castings on horizontal axis machines is devoted to the production of cylinder liners and piston ring pots. Such castings are produced in permanent metal moulds, and are relatively small when compared with the pipes previously discussed. Centrifugally cast pipes and similar products are commonly made in lengths up to 16 ft., whereas cylinder liners, etc., rarely exceed 3 ft. in length, and the majority of such castings are less than 2 ft. long. During the period 1919–23 the manufacture of these castings was pioneered in this country by Stokes. The process is carried out in metal moulds

maintained at a temperature approaching 600° C., in contrast to the systems previously outlined, which utilise either water-cooled or sand moulds for cast iron. Bronze castings of a similar type are produced in metal moulds which are maintained at a maximum temperature of 150° C. In cast iron practice, a single mould is used in each machine, and is maintained at the necessary temperature by the quantities of molten iron used in the process. When bronze castings are made, a number of moulds are used, and as each casting is produced in turn, the mould and casting are removed from the machine, being replaced by a fresh mould at the correct temperature. The various techniques are adopted for metallurgical reasons. Cast iron pipes should be machinable, if necessary, and hence a chilled white iron is undesirable. Heated moulds are used for cast iron cylinder liners and piston ring pots, in order to obtain a pearlitic structure, as some workers believe that undercooled graphite and the ferrite normally associated with this type of structure is undesirable in piston ring and similar applications. Bronze castings are produced in relatively cool metal moulds in order to promote the formation of small, well distributed (α & δ) eutectoid, and a fine grained matrix. This structure has been proved to impart the maximum wearing properties which are desirable in these products.

Many types of machine have been devised for this purpose, but most are similar to the original Stokes design, and a description of the latter will therefore suffice for all. The casting machine is essentially a horizontal shaft supported on two bearings. A face plate is fitted to one end of the shaft, and the latter is driven by means of an electric motor connected to the opposite end. A cylindrical cast iron housing is attached to the face plate, and accommodates a cylindrical metal mould. An annular disc of iron or steel fits inside the housing, and is kept firmly in place against the end of the mould by a number of tapered cotter pins. The latter are driven into slotted bolts which are an integral part of the mould housing, extending beyond the annular disc. These pins are driven into the bolts in an anti-clockwise direction, and therefore tend to become even more firmly seated as the mould assembly gathers speed. The diameter of the hole in the metal disc controls the bore dimensions of the casting if excess metal is transferred to the mould.

Molten metal is handled by a casting machine, which consists of a wheeled carriage mounted on rails. The carriage bears a metal reservoir which is essentially a shallow dish-shaped container lined with refractory, and having a tubular metal runner slit longitudinally to facilitate pouring. In practice, the machine is started, and the mould assembly allowed to reach the desired speed. A known quantity of molten metal is transferred to the reservoir, and the carriage moved forward until the tubular runner is projecting inside the rotating mould. The operator turns a hand-wheel which is geared to the metal reservoir, and the latter is tilted, enabling the liquid metal to flow along the tubular runner and hence through the slot. Metal transfer is rapid, and a tubular casting is produced in about five minutes. The empty container is removed from the mould and cleaned in readiness for the next casting cycle. When the appropriate time has elapsed, the rotating mould assembly is stopped by cutting off the power supply, and using the brake system provided. The casting is then extracted.

TABLE I.

	Solid 8-sided ingot	"Slush cast" 16-sided ingot	Cored ingot	Centrifugally cast ingot
Ingot size	6–7 ft. diameter. 20 ft. long including feeder	6 ft. diameter. 14 ft. 6 in. long	6 ft. O.D. 3 ft. 8 in. I.D. 17 ft. 4 in. including feeder	5 ft. 10 in. O.D. 3 ft. 3 in. I.D. 14 ft. 4 in. long
Weight of metal cast	145 tons	92 tons	75 tons	57 tons
Final product	45 tons	5 ft. 10 in. O.D.	3 ft. 10 in. I.D.	13 ft. 8 in. long
Percentage recovery	31%	49%	60%	79%
Machining time	185 hrs. 73 hrs.	55 hrs. 73 hrs.	65 hrs. 79 hrs.	80 hrs. 73 hrs.

Very Large Centrifugal Castings

Extremely large castings are occasionally produced on horizontal axis machines, bronze and steel castings weighing more than 20 tons, measuring up to 44 in. diameter and 30 ft. long, having been made in this country. Refractory-lined steel moulds are used, and the complete charge poured in approximately 100 secs. Such products are used for paper making machinery and chemical plant.

Simoneit and Radeker have described the production of very large steel ingots for high pressure boiler drums. Such ingots may be made hollow in order to facilitate the subsequent forging operation. British practice consists in the static casting of large solid ingots, which are later bored and forged into shape. Normal piercing and drawing processes are limited to comparatively small ingots, and very large tubular products cannot readily be obtained by such techniques. It has already been established that cylindrical ingots may not be obtained in a wholly sound condition; segregation becomes a problem in very large solid ingots owing to the time factor involved in solidification. The multiple-sided ingots which are usually cast are liable to prove expensive, since the yield is low, and machining cost high. In German practice, hollow ingots are sometimes made by centrifugally casting the required amount of metal in a horizontal axis mould. The latter should be made of haematite cast iron, or be of water-cooled steel construction.

Molten metal is introduced into the rotating mould by means of a refractory funnel arrangement, and mould erosion prevented by a prior addition of dry sand. The latter is added in sufficient quantity to form a layer 5 mm. thick on the inner face of the rotating mould. Details of various methods used to produce large steel ingots are given in Table I and afford an interesting comparison.

It will be seen from the figures quoted that considerable economies are possible, when centrifugal methods are used to produce large ingots.

Vertical Axis Casting

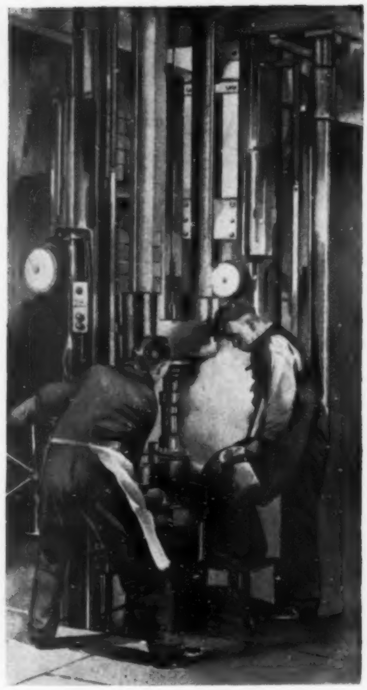
Comparatively simple components such as gear blanks are produced in large numbers on vertical axis machines. More intricate shaped castings are also made in this manner. The interior of castings produced on horizontal type machines is cylindrical in shape. The cavity formed in castings made on either vertical axis or inclined axis machines is not cylindrical, being controlled by the angle of the axis of rotation. As the latter is

increased, the casting bore becomes tapered, finally assuming a parabola shape when the axis of rotation reaches 90° to the horizontal plane. Some variation is obviously possible in the internal shape of castings not produced on horizontal axis machines, and such differences are responsible for the somewhat loose nomenclature which has been adopted in the industry.

Terms such as "centrifuging," and "semi," "true" and "simple" centrifugal casting are not precise. Two main techniques may be distinguished in general practice; they are, that in which liquid metal or alloy is poured into a rotating mould, and another in which a stationary mould is filled with molten material before subsequent rotation. The centrifuge is a well-known piece of laboratory apparatus, and is invariably filled before rotation. It may be convenient, therefore, to regard centrifuged castings as those which are produced by the rotation of any mould when the latter has been filled prior to rotation. All other castings made in rotating moulds may conveniently be described as centrifugal castings. Optimum properties are obtained from the latter, since centrifugal force is used to the best advantage. In certain cases, if the mould material used is liable to be attacked by the liquid alloy, it may be useful to allow a protective layer of solid material to form on the mould wall before rotation begins.

Courtesy of Leyland Motors, Ltd.

Fig. 4.—Steel castings sand cast centrifugally.



Courtesy of John Holroyd & Co., Ltd.

Fig. 5.—The production of cored bronze billet by centrifugal means.

Sand or metal moulds may be used, depending upon the intricacy of the castings concerned. Sand cores can be used in relatively simple metal moulds to obtain additional detail if required, and metal moulds may be machined internally to provide corresponding casting profile. Grey cast iron is the most popular metal mould material, though alloy steel and aluminium bronze moulds have been used. Graphite moulds have found useful application, though the latter is limited by the tendency of graphite to oxidise at normal casting temperatures. An oil-bonded sand of high dry-strength finds wide application for sand moulds used in vertical axis centrifugally cast work. The greater flexibility of the sand moulding process controls its application, and this feature is of great value when intricate castings are made. Metal moulds are used whenever the design and quantity factors are favourable.

Typical shaped centrifugal castings are illustrated, and the products made on vertical axis machines range from grinding balls for ore crushing equipment, to steel gears, small marine propellers, and automobile crankshafts. Extremely small centrifugal castings have been used in dentistry for many years; very fine grained refractory mould material is essential in the production of such castings. Large castings, such as tank turret covers, and steel spur gear rings for gun mountings were regularly produced during the recent war. The latter castings measured seven feet in diameter and were produced in pairs by stack moulding methods. Such methods can easily be adapted to vertical axis technique, provided that great care is taken to locate accurately each mould part in turn. High yields are obtained by stack moulded centrifugally cast methods.

The running method used in vertical axis work is dependent upon the design of the casting involved. Ring shapes are easily made by simple top pouring methods, molten metal being distributed evenly around the inner mould wall during rotation, and the required wall thickness obtained by controlling the quantity of metal added. Small and relatively intricate shaped parts may also be produced on vertical axis machines. The requisite mould cavities are disposed symmetrically about a central running system, so that the former tend to assume a continuous outline similar to the rim of a wheel; the ingates in the running system may be regarded as wheel spokes, which are fed in turn by the hub or central down-runner. A pressure feeding effect is obtained during mould rotation and the shrinkage normally occurring should be confined to the runner system. Solid or cored castings can be produced in this way, and the automobile castings illustrated are typical of shaped castings produced by centrifugal methods.

Precautions Desirable

Certain precautions are desirable during centrifugal casting operations. Very large stresses are set up during the high-speed rotation frequently employed in this process. Sand moulds should be adequately

reinforced with steel retaining boxes; both sand and metal moulds should be securely attached to the rotating mechanism. All moulds which are rotated should be provided with adequate splash guards, but overfilling of centrifugal moulds should be avoided by careful measurement of the liquid metal involved. As the latter is generally measured on a volume basis, overheating should be avoided. The recognised disadvantages attached to overheated metal when statically cast, apply equally to the centrifugally cast product, and the additional grain refinement found in the latter material will be absent if overheated metal has been used. Down runners should be comparatively tall, in order to reduce the possibility of metal ejection when a filled mould is rotated at high speed.

Much defective centrifugally cast material is due to incorrect spinning technique. Vibration may readily occur in centrifugal casting equipment unless due attention is paid to maintenance. Northcott has pointed out that banded structures may be due to vibration of the mould assembly as the casting solidifies, coupled with the existence of a steep temperature gradient.

Speed of Rotation

It is desirable to use the minimum speed of rotation in every case, in order to secure maximum output. Excessive speeds are uneconomic, since time is expended in reaching such speeds, and in braking when the casting cycle is complete. If the minimum speed is not reached, droplets of liquid metal are detached from the mass, and an inferior casting is obtained. Excessive speed of rotation increases the internal pressure to which the casting is subjected and the material will be prone to cracks or tears. The speed of rotation is normally inversely proportional to the casting diameter, and the optimum speed for any casting may be calculated in several ways. The principles involved have been discussed by many workers.

These calculations are based upon several factors, and do not take into account other points of equal importance. Northcott, and other workers, have shown that the effects of slip between the mould surface and the outer layer of molten metal must influence the speed of the latter. Northcott has also shown that the metal may only attain the same speed as the rotating mould when the increased viscosity due to temperature decrease causes an increased force to be applied. Donoho is in agreement, and also states that the "times gravity" factor can be less for cold moulds than for hot moulds or sand moulds.

In practice, castings are allocated for production, according to size and weight. Some tolerance is apparently permissible in the speed of rotation, and only three principal speeds may be required to produce the majority of castings.

The Holfos Process

A British centrifugal casting technique which differs radically from usual practices is that applied in the production of chilled phosphor bronze billet or stick. Cored phosphor bronze is widely used in light engineering and when this can be supplied chilled both internally and externally, the valuable wear resistance properties are much improved. Many attempts have been made to produce this type of chilled cored bronze stick on a large scale, but only one process is now established. In this Holfos process, the material is centrifugally cast, using a rotating chill core which is progressively withdrawn during the casting operation. The product is homogeneous and is superior to that obtained by other means.

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Outsize E.S.C. Castings for U.S.

English Steel Corporation, Ltd., of Sheffield, have received recently orders for a number of large steel castings required for plant to be built in the U.S.A. for the American Defence Programme. Although some of the castings have already been produced, and the first is due for despatch this month, it is only now that the American authorities have agreed to the release of information concerning this work.

These orders are of particular importance and interest not only from the dollar earning angle, but also because they call for steel castings of greater size and weight than any previously produced in Great Britain. The heaviest of the castings will weigh, when despatched from Sheffield, approximately 170 tons, and required approximately 210 tons of liquid steel for their production. The patterns used for this work are as large as a normal pre-fabricated house, and production called for split-second timing of several furnace casts.

Production, transport and lifting of these tremendous parts have presented unusual problems even to English Steel Corporation, who have been producing very heavy cast and forged components for many years.

A special road vehicle is being manufactured to transport the castings from Sheffield to the port of despatch, and the gross weight of vehicle and casting will be of the order of 230 tons.

Cathodic Protection Specialists Combine

Messrs. F. A. Hughes & Co., Ltd. and Westinghouse Brake & Signal Co., Ltd., pioneers of cathodic protection, are collaborating and pooling their respective experience of this scientific method of corrosion prevention with the object of offering their combined technique in the most practical and comprehensive form now known as "The Guardion Service." This embraces the supply of the well known "Guardion" and "Westalite" cathodic protection equipment, and offers full consultative and design facilities as well as surveys in the field. It is applicable to all forms of buried or water-immersed metallic structures. Full particulars can be obtained from Messrs. F. A. Hughes & Co., Ltd., Cathodic Protection Division, Bath House, 82, Piccadilly, London, W.1.

Integrated Plant in Operation at Shotton

First Stage of Development Scheme Completed

The first stage of the extensions to the Shotton Works of John Summers & Sons, Ltd. is now completed, and the new plant, comprising coke ovens, blast furnace, power house and melting shop was seen in operation by H.R.H. The Duke of Edinburgh on a recent visit. A brief description of some of the principal features of the new plant is presented in the following pages.

THE seal was set on another important step in the re-organisation of the iron and steel industry when, at the end of last month, H.R.H. The Duke of Edinburgh visited the Shotton Works of John Summers & Sons, Ltd., to see in operation the recently completed first stage of the company's development programme. The firm was founded at Stalybridge in 1851 by John Summers, but it was under the guidance of the second generation that the move was made to the low-lying marshland at Shotton, which offered space for almost unlimited expansion. Now the third generation —for the present chairman of the company, Mr. Richard Summers, is the grandson of the founder—has carried through a £17,000,000 scheme to replace and augment the previously existing steelmaking capacity.

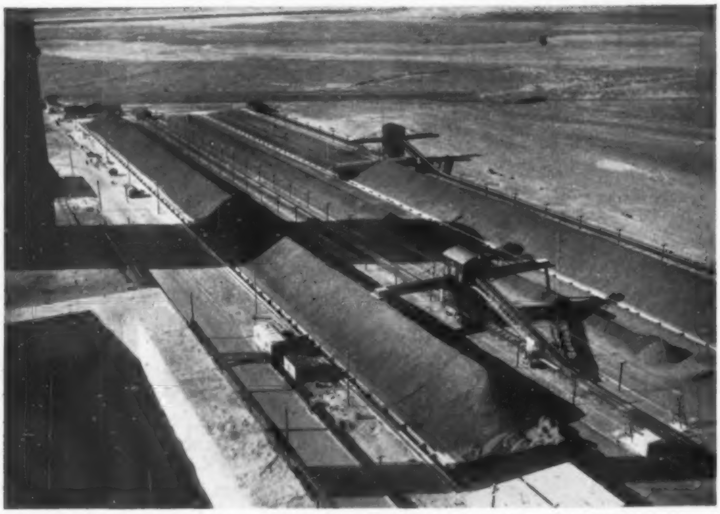
The end product of the Summers works is sheet steel, some 40% of the automobile sheet steel used in this country being produced there together with other classes of sheet and strip and a small tonnage of galvanised sheets. Just before the last war hot and cold continuous strip mills were installed, but the outbreak of hostilities called a halt to further developments. In 1939 the steelmaking capacity consisted of two steel plants which depended on the supply of pig iron and scrap from a subsidiary and outside sources. These melting shops were deliberately left in order to gain experience in making steel suitable for rolling into strip form before embarking on new schemes. Suitable techniques were developed during the war, and when peace came, plans were drawn up to modernise and extend the steelmaking capacity of the plant in order to utilise the hot and cold mills to a production more nearly approaching full capacity. The limited supply of scrap available made it imperative to include provision for the production of pig iron as a basis for the increased steel production.

Plans for the new developments were accordingly laid in 1946, the extensions being divided into two stages. Stage I included the erection of a new melting shop with eight 150-ton capacity open-hearth furnaces; a blast furnace with a 27-ft. diameter hearth and all ancillary equipment; a coke-oven plant comprising two batteries of 44 ovens each together with a by-product plant; and a new power station and blower house. Stage II will involve the duplication of the blast-furnace plant and the erection of a further 88 coke ovens together with the necessary by-product plant. The melting shop is capable of being extended by a further four furnaces.

Site preparations began in 1947 and this involved the creation of a vast artificial plateau, some 12–15 ft. above the marshland level, by means of pumping sand from the Dee estuary. In all, some six to seven million tons of sand were pumped on to the site, the water being allowed to drain off, leaving a solid foundation of sand.

It has taken nearly six years to complete Stage I, which has made the works into a fully integrated plant, but all the units have been brought into production during the past few months. In the account which follows, brief particulars are given of some of the main sections of the plant.

Panoramic view of the new plant at Shotton taken across the Dee sands. On the left is the coke-oven plant, in the centre the blast-furnace plant and power station, and on the right the melting shop.



The coal beds with wing tripper in foreground and a reclaimer in front of a second wing tripper top centre.

Coal Handling and Blending

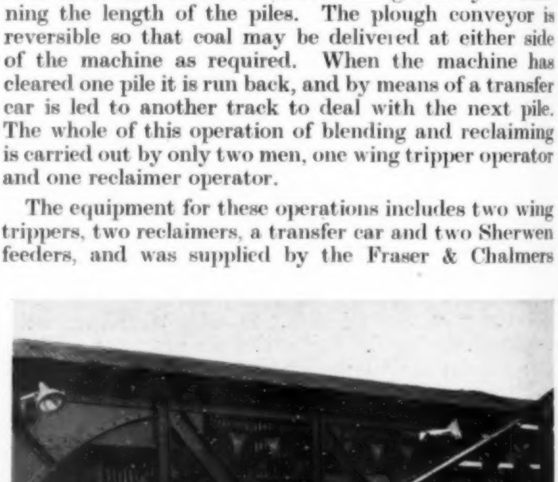
The shortage of first-quality coking coals in this country has resulted in increased attention being paid to the blending of different coals for the manufacture of metallurgical coke. The importance of blending is emphasised at Shotton, which is remote from coal-producing areas, and special provision has, therefore, been made for the handling, stocking and blending of coals from any number of sources. Because the number of coals to be blended was uncertain, it was considered that the orthodox type of blending bunkers would not be entirely satisfactory. It was also essential that a coal stock should be provided on site which would be completely used every few weeks to prevent weak coals deteriorating. It was accordingly decided to use the Robins-Messiter system of bedding and blending, which was originally developed for blending copper ores and later applied to iron ores. This is the first occasion, however, on which it has been used for coal blending.

The coal-handling plant has a nominal capacity of 300 tons/hr. and will work on two shifts only when Stage II is complete. Coking coal is received in gravity sorting sidings with standage for 500 full wagons and 200 empty wagons; in addition reception loops are provided for 60 wagons. From the sidings, the wagons gravitate into two wagon hoists which elevate them some 30 ft., from which elevated position they run down a slight incline through two side discharge tipplers fitted with automatic weighing and recording mechanisms, the coal being discharged into receiving hoppers feeding the belt conveyors to stock.

The Robins-Messiter system consists of two separate operations: (1) bedding the material, and (2) reclaiming. The beds are formed by the use of travelling wing trippers which automatically traverse the length of the bed, depositing thin layers of coal one above the other from end to end of the pile. Accurate blending, which requires approximately the same amount of coal in each layer, is achieved by ensuring that the feed to the conveyor system is regular and that in the event of the feed being interrupted the tripper is stopped immediately until supplies of coal are resumed. Two speeds for the travelling wing tripper are provided, since when travelling away from the feed end of the belt it receives less coal than when travelling towards it. The boom conveyor of the wing tripper is reversible so that when a pile has been completed on one side the conveyor may be reversed to make another pile on the other side of the machine. The piles contain 12,000 tons of coal and at 975 ft. have a length far in excess of any previous installation.

Reclaiming of the piles is carried out by a machine which consists of a travelling bridge carrying the two essential reclaiming units, the harrow and the plough conveyor. The harrow is fitted to the front of the machine and reciprocates slowly across the end face of the pile, dislodging a small cross section which, as it rolls down into the plough conveyor, is intimately mixed by hundreds of tines equally spaced over the harrow surface. The inclination of the harrow is adjusted to the angle which gives a steady flow of coal down to the plough conveyor, which carries the blended coal to the side of the machine where it falls on to one of the three reclaiming conveyors running the length of the piles. The plough conveyor is reversible so that coal may be delivered at either side of the machine as required. When the machine has cleared one pile it is run back, and by means of a transfer car is led to another track to deal with the next pile. The whole of this operation of blending and reclaiming is carried out by only two men, one wing tripper operator and one reclaimer operator.

The equipment for these operations includes two wing trippers, two reclaimers, a transfer car and two Sherwen feeders, and was supplied by the Fraser & Chalmers



Close up of plough conveyor showing blended coal entering the longitudinal conveyor trough.

Engineering Works of The General Electric Co., Ltd., to the order of Simon-Carves, Ltd., who designed and supplied all the belt conveyors and civil engineering equipment as part of their complete coke oven contract.

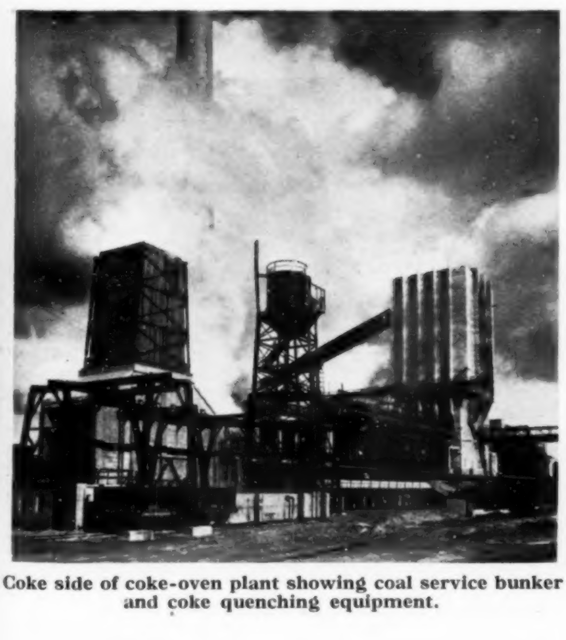
Coal from the reclaiming conveyors is fed by four further conveyors to the crusher house, where three interconnected Fraser & Chalmers Pennsylvania hammer mills crush it to a suitable size for coking, prior to its being delivered by the main conveyor to the 5,000-ton capacity reinforced concrete service bunker.

The ore stock-yard and bridge. On the right can be seen the high line and part of the blast-furnace plant.

Coke-Oven Plant

Of the four 44-oven independent batteries which will ultimately form the coke-oven plant, and produce 16,000 tons/week, two are in operation and the remaining two under construction as part of Stage II. The ovens are of the Simon-Carves entire underjet type, arranged for firing with either coke-oven gas or clean, cold blast-furnace gas. The gases are delivered under pressure to each individual heating flue, and air can be delivered under pressure or by natural draught as required. Each oven heating wall may be changed from one gas to the other in a few minutes, so that any number of ovens may be heated by blast-furnace gas or coke-oven gas.

The system combines a twin divided regenerator with a hairpin heating flue, the regenerator being divided along its length by diaphragms, so that each hairpin heating flue has its own regenerator compartment for air, blast-furnace gas and waste gas from the regenerator sole flue upwards. Blast-furnace gas and air are admitted under pressure to each regenerator division through calibrated nozzles. Rich gas is also admitted through calibrated nozzles fixed in distributing pipes according to standard practice. Waste gases are withdrawn from the end of each twin regenerator through a reversing valve which admits air to the regenerator when using natural draught: one valve serves two regenerators.



Coke side of coke-oven plant showing coal service bunker and coke quenching equipment.

When firing with rich fuel gas, both compartments of the twin regenerator are supplied with air when the neighbouring twin regenerator is taking waste gas: the flow is reversed at pre-determined intervals. All the regenerators and sole flues are divided along the centre line of the battery, and waste gas valves are fitted along ram and coke sides of the regenerator faces. The waste gas flues terminate in a 247-ft. chimney stack which serves all the 88 ovens.

Two complete sets of oven machines are provided for the two batteries now in operation. They are of normal design with the exception that the 4-hopper charging car is fitted with Locker-Traylor vibrating feeders to each hopper, to ensure a uniform flow of coal from the charging car into the ovens. The oven doors are of the luted type with self-locking latches.

A quenching station is provided at one end of the batteries, the tower being built of red brick surmounted by a chimney of timber construction. The usual breeze settlement ponds are installed and a conical bottomed quenching tank delivers through an automatic quenching valve to full cone type sprayers inside the tower. A 200-ft. long coke wharf of reinforced concrete paved with blue brick is fitted with the usual type of finger gates and discharges on to a wharf belt.

The coke-handling plant is designed to deliver direct to the blast furnace bins at a rate of 125 tons/hr. with the usually primary screening of sizes below $1\frac{1}{4}$ in. The centrally-located primary screen house receives coke from the main wharf belts which are 48 in. wide. Revolving grizzley screens remove all coke below $1\frac{1}{4}$ in. and the "throughs" from the grizzlies are delivered over 24 in. wide belts to a secondary classifying screen of the reciprocating type, which separates into three sizes and discharges into three 35-ton compartments of a reinforced concrete bin, where arrangements are made for feeding into rail or road wagons.

The "overs" from the grizzlies travel by a 40-in. belt

General view of the blast-furnace plant.

conveyor to the blast-furnace stock bins, where another belt conveyor distributes the coke into selected bins by means of a reciprocating reversible shuttle belt. Arrangements are made for removing any smalls formed during passage through the blast-furnace bins before the coke enters the furnace skip. These smalls are transferred to the classifying screens previously mentioned.

The by-product plant for Stage I operates on the semi-direct ammonia recovery principle. Normally, the whole of the gas produced in the ovens is cooled, cleaned, treated for the removal of ammonia and benzole, and is then delivered either through a waterless gas-holder for use at the ovens, or direct to the steelworks. The Stage I by-product plant will deal with the gas from the 88 ovens and provision has been made for extensions to take gas from a future 44 ovens. A further by-product plant, operating on the indirect principle, will be installed to deal with the gas from the remaining 44 ovens of Stage II.

Blast-furnace Plant

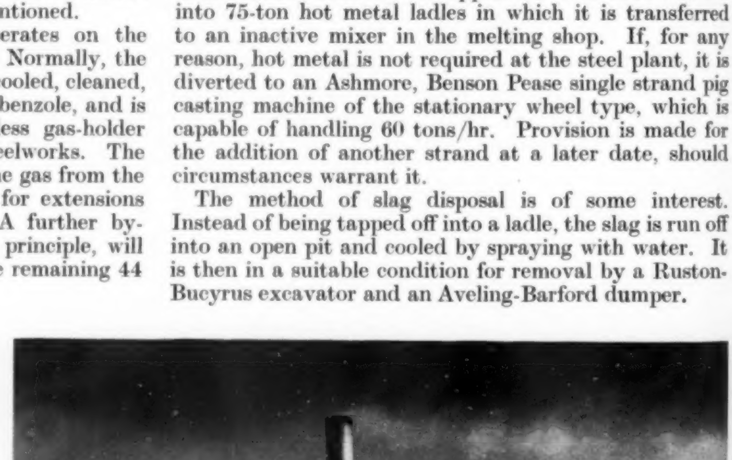
The blast-furnace plant, comprising ore unloading, crushing and screening plant, sinter plant, blast furnace and ancillaries, gas cleaning plant, etc., was the responsibility of Head Wrightson & Co., Ltd., in association with Head Wrightson Engineering Division. The blast furnace itself, with its 27-ft. diameter hearth, is the largest of its kind outside the United States, and has an output of more than 1,000 tons of iron a day with the designed burden of foreign ore. At present a proportion of home ore is being used, with a corresponding drop in iron output.

Imported ore is brought from Birkenhead docks, in trains of the company's own 50-ton hopper wagons, and taken to the ore bench where it is unloaded in a matter of minutes by dumping the ore into a series of hoppers. Alternatively, the ore can be stored in an ore stock-yard served by a 180-ft. span ore bridge. From the hoppers a tray feeder delivers ore on to a conveyor belt which carries it directly to the crusher house. Crushed ore is screened, and all material of $-2\frac{1}{2}$ in. $+\frac{3}{8}$ in. is transferred direct to the furnace stock bins by means of conveyors and high-line transfer cars, whilst the $-\frac{3}{8}$ in. material is transferred to a sinter plant of the continuous strand type, 72 in. wide $\times$ 120 ft. long with 20 wind boxes. The plant can handle 1,800 tons/day.

The furnace itself is of the most modern design, and is equipped with a McKee improved type distributor. Ore, limestone and coke are withdrawn from the high-line bins into two scale cars, each of 500-cu. ft. capacity, from which they are loaded into the 250-cu. ft. capacity cars of the double skip hoist. When fully loaded, the furnace holds some 8,000 tons of material. For heating the blast, there are three hot-blast stoves, each 26 ft. in diameter and 102 ft. high. They are provided with Freyn-type burners and each has 200,000 sq. ft. of heating surface.

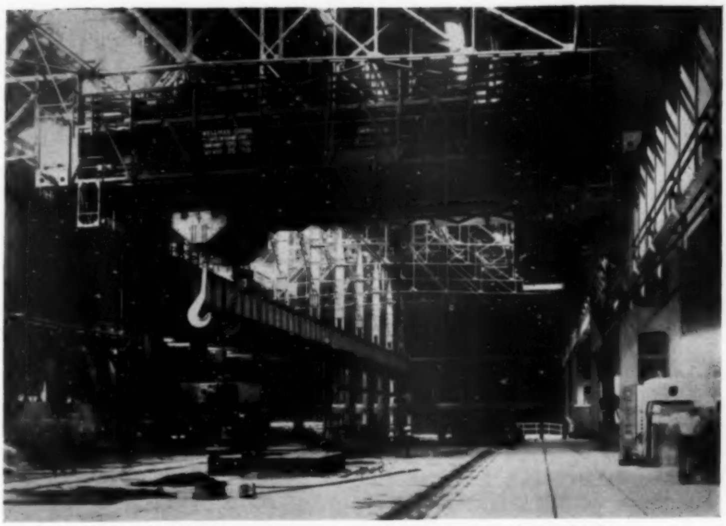
The products of the blast furnace are, of course, iron, slag and blast-furnace gas. As in all integrated plants, the iron is normally charged to the open-hearth furnaces in the molten state. It is tapped from the blast furnace into 75-ton hot metal ladles in which it is transferred to an inactive mixer in the melting shop. If, for any reason, hot metal is not required at the steel plant, it is diverted to an Ashmore, Benson Pease single strand pig casting machine of the stationary wheel type, which is capable of handling 60 tons/hr. Provision is made for the addition of another strand at a later date, should circumstances warrant it.

The method of slag disposal is of some interest. Instead of being tapped off into a ladle, the slag is run off into an open pit and cooled by spraying with water. It is then in a suitable condition for removal by a Ruston-Bucyrus excavator and an Aveling-Barford dumper.



The power station and blower house.

The hot blast-furnace gas leaves the top of the furnace by four uptakes which join, first in pairs, and then in a single downcomer leading to the main dust-catcher. On leaving the main dust-catcher, the gas passes successively to a secondary dustcatcher of the cyclone type, a gas washer and two electrostatic precipitators each incorporating 260 tubes 12 in. in diameter and 15 ft. long. The gas from the precipitators goes to a 2,000,000-cu. ft. capacity gasholder prior to use on stoves, coke ovens and the boiler plant of the new power station.



Wellman 125-ton crane for charging hot metal.

Blower and Power House

An important item of the extensions is the new blower and power house, which supplies air for the blast furnace and power to all sections of the works, at the same time consuming a large amount of blast furnace gas for steam raising. At present there are two Parsons turbo-blowers, each with a nominal rating of 75,000 cu. ft./min. at a delivery pressure of 30 lb./sq. in. gauge. The maximum rating of each turbine is 8,970 b.h.p. at 2,740 r.p.m., and standard wide-range governors are fitted so that, when the volume and pressure regulators are not in use, the set may be run at constant speed. The air control system prevents surging when only small quantities of air are required, maintains constant air delivery irrespective of variations in resistance of the system, and overrides the constant-air regulator should the furnace resistance build the pressure up to a pre-determined value. A further turbo-blower is scheduled under Stage II of the development scheme which provides for the erection of a second blast furnace.

The new power station supplements the supply taken from the B.E.A. and the existing power station in the works. The generating equipment comprises two Parsons turbo-alternators, each of 12,500 kW rating. Unlike the blower turbines, which are direct condensing, these prime movers are pass-out type machines supplying process steam to the main works system at 160 lb./sq. in. gauge.

In an annexe to the power station building are electrical and fuel control rooms from which the distribution of power, steam and gaseous fuels are controlled for the whole works.

The boiler plant comprises five Thompson boilers, of which three can be fired by stoker or blast-furnace gas, and two are for blast-furnace gas firing only. The respective individual boiler capacities of the two types are 85,000 lb./hr. and 90,000 lb./hr. Steam conditions at the boiler stop valves are 450 lb./sq. in. gauge and 760° F. total temperature. Feedwater treatment plant and evaporator plant are also housed in the boiler bay.

Steel Plant

There are two main sections of the steel plant—the raw materials building, in which all solid raw materials are loaded into charging boxes, and the melting shop proper. The floor of the raw materials building is on the same level as the melting shop stage, to which it is connected by a bridge. Charging boxes are conveyed between the raw materials building and the melting shop on bogies running on a special rail system: all materials are weighed in transit.

Melting shop stage with Arrol charger in foreground.

The major items of plant in the melting shop comprise two 1,200-ton inactive hot metal mixers and eight 150-ton fixed basic open-hearth furnaces. The latter, built by Salem Engineering Co., Ltd., have single uptakes, and provision is made for firing by coke-oven gas and/or oil. A waste-heat boiler is attached to each furnace, and delivers process steam at 160 lb./sq. in. to the works system. Each furnace is provided with a pressurised control cubicle in which the measuring instruments and automatic controllers are accommodated. The installation, which is claimed to be the most comprehensive automatic control

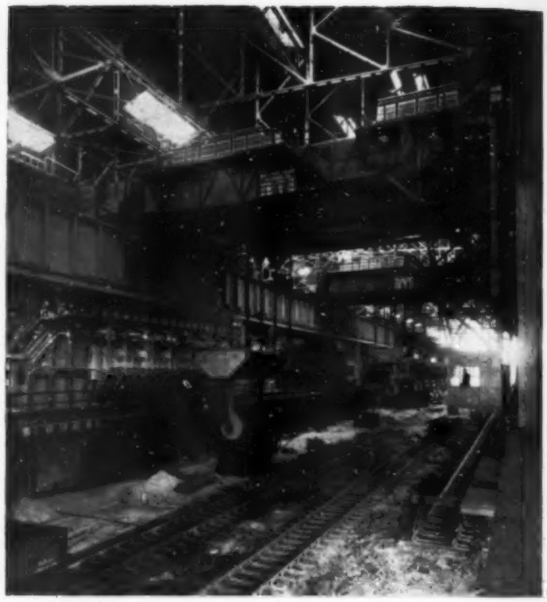
scheme yet introduced on an open-hearth plant in this country, is the result of development work carried out by Tinsley (Industrial Instruments), Ltd., in close collaboration with the steel company: a description of the control system appeared in our January issue.

The bogies carrying the charging boxes run on rails immediately in front of the furnaces, and four Arrol 8-ton ground-type non-rotating charging machines discharge the contents of the boxes into the furnaces. Hot mixer metal is handled by two Wellman 125-ton ladle cranes and an electrically driven transfer car running the full length of the melting shop. The ladle beam of the cranes has four-point suspension on 16 falls of rope, the hooks being spaced at 13 ft. 4 in. centres to suit the hot metal ladles. For tilting the ladles, there is an auxiliary trolley of 25 ton capacity. The crane span is 78 ft. and the gantry rail level is 60 ft. above flow level, and as the cranes have a short cab, the latter is situated at a comparatively high level to give good visibility when pouring. The fully-laden weight of the cranes is 385 tons, and the speed of travel along the shop is 225 ft./min.

The casting bay is equipped with two Wellman 250-ton cranes for carrying the ladles filled with molten steel, and for holding whilst the steel is teemed into moulds standing on ingot cars. The ladle beam has four-point suspension on 32 falls of rope, the hooks being spaced at 15 ft. 6 in. centres for engagement in the ladle trunnions. An auxiliary trolley is provided with two hoisting motions, one of 50-ton and one of 15-ton capacity. The crane span is 78 ft. and the gantry rail level is 54 ft. above floor level. Suitably insulated and sealed for the future installation of air-conditioning equipment, the driver's cab is at a level approximating that of the melting shop stage. The fully laden weight of the cranes is 750 tons, and the speed of travel along the shop is 200 ft./min.

Instrumentation

Recent years have seen increasing importance attached to instrumentation, and of no industry is this more true than of the steel industry, where, in particular, instrumentation of open-hearth plants has led to an appreciable increase in production. In the case of an integrated plant such as Shotton, there is the added necessity for a co-ordination of the various individual plants, particularly with regard to such things as fuel production and consumption. The main instrumentation of the new extensions was the responsibility of George Kent, Ltd., working in close co-operation with the steel company, and with the main contractors for the various sections of the plant.



View of pitside showing Wellman 250-ton ladle crane.

Anglo-U.S. Steel Castings Agreement

An important agreement has recently been concluded between two of the largest producers of special steel castings in the U.S.A. and Great Britain—General Steel Castings Corporation, of Granite City, U.S.A., and English Steel Corporation, Ltd., of Sheffield. General Steel Castings Corporation are the foremost producers in the world of special castings for locomotives, carriages and wagons.

Under the agreement English Steel Corporation will produce in quantity special railway castings of a type which they have already been developing, such as one-piece bogies, locomotive frames, etc. The Trade name of these products, appropriately enough, is "Commonwealth." The benefits of the joint enterprise are clear. There will be an interchange of "know-how" on design and foundry technique, and a consequent expansion of the scope of production and sales, particularly in the vital field of exports.

Already this work has begun. Senior officials of English Steel Corporation are in the United States, five Foundry technicians recently sailed in the *Queen Mary* and more are to follow this year. They will study the practices and techniques of the General Steel Castings Corporation relevant to the agreement; they will also visit other works in connection with products already made by English Steel Corporation, Ltd. The importance of the work done by English Steel Corporation personnel in the U.S.A., Canada and the other vital world markets can be measured by the fact that four out of every five of the Corporation's products are directly or indirectly exported.

Instructional Films on Iron Making

Three films on the blast furnace are the first in a series of instructional films on basic processes to be produced by the British Iron and Steel Federation. The films are intended to cover the subjects of the City and Guilds Iron and Steel Operatives' Course, and to be used in class-rooms in conjunction with other Federation visual aids—wall charts, film strips and lecture notes. To assist instructors, notes are being prepared which will include the complete commentary of each film and will contain, in addition, a number of supplementary notes, amplifying points made in the film and making suggestions for more detailed instruction. The titles of the films are: "What Goes into the Blast Furnace," "Making Iron," and "What Comes out of the Blast Furnace," the running times of the first two being 15 minutes and of the last one eight minutes. Besides straightforward plant shots, considerable use is made of animated diagrams in explaining the processes.

Buying Quality in Light Metal Castings

Use of Standard Specifications Urged

In times of keen competition there is a strong temptation to lower standards of quality and service, and thus cheapen the product in order to keep up the volume of production. In this article the Light Metal Founders' Association point out the dangers of such a course, recognizing that the growth of a young industry such as theirs is likely to be retarded, not accelerated, if short-sighted methods of development are adopted. They urge that, in ordering light alloy castings, buyers should in their own interests always insist on conformity to standard specifications.

PERHAPS the most generally recognized feature of the past fifteen years in the field of metallurgy has been the tremendous increase in the volume of output of light metals. The impetus was provided, of course, by the necessity of building vast numbers of aircraft, for which lightness and strength were prime requisites. These twin requirements had to be fulfilled with certainty and precision—there was no room for guesswork or approximation, so materials were described and defined by standard specifications.

Peacetime uses of light metals do not as a rule call for the highest strength/weight ratio, either on technical or economic grounds, but it is none the less essential to make sure of the consistent quality of the materials to be used for any engineering purpose. In 1945 the British Standards Institution issued for the Ministry of Supply the BS/STA7 Services Schedule of Aluminium and its Alloys, which was widely used as a general reference until the publication in 1949 of a series of British Standard Specifications covering aluminium and aluminium alloy products for general engineering purposes.

Though the benefits of standardization apply to all products, in this article we are concerned only with light alloy castings, and an enumeration of the main points affecting castings in particular may not be out of place here. The objects are : to restrict excessive variation of alloys for the convenience of founder, finisher and user alike ; to provide a generally-accepted common reference in the welter of proprietary names ; to enable the customer to appraise the nature of the materials offered, and satisfy himself that they are suitable for the purpose for which they are required ; to define methods of inspection and testing, and to specify the chemical composition and property values appropriate to each alloy ; and to establish in advance an agreed procedure to be followed in the event of dispute.

Specifications Cover Range

B.S. 1490 : 1949 provides the means of attaining all these objects. By careful deliberation a series of specifications has been drawn up to cover a range of alloys that will satisfy all normal engineering requirements. It includes not only the strongest available alloys, used so extensively and successfully in aircraft and wherever lightness has to be accompanied by high strength, but also the more workaday materials that possess adequate strength for lightly stressed articles and are less costly to produce. It also includes alloys which are specially suitable for particular types of service—for example, by reason of their resistance to corrosion, or their retention of strength at elevated temperatures, or their ability to acquire a decorative finish.

The existence of a series of specifications makes it easier to ensure that alloys used are suitable for the purpose which the castings are to serve, both by narrowing the range of choice to include only recognized materials and because the advice of founders that produce castings to specification is freely given and reliable. The importance of choosing the right alloy for any given job is widely appreciated nowadays, but was not always so. For instance, a year or two ago an investigation was held into the failure of aluminium alloy components of public service vehicles built prior to 1939. Nearly all the cast specimens analysed were found to conform to no British Standard as regards composition, or to contain excesses of certain constituents detrimental to performance. Such haphazard ordering of castings would be unusual, and inexcusable, now.

With standardization firmly established, the light metal industry in Britain is more fortunate than those in some other countries. It would be a thousand pities if this advantage were lost under pressure from competition. In the present trade recession there is a very real temptation to buy in the cheapest market, with less insistence on quality. Within the last twelve months buyers of industrial goods—materials, semi-finished products, plant and equipment—have become much more price-conscious. The world-wide shortages of both capital and consumer-goods have now been made up as far as ability to pay for them will allow : with more goods available, the customer is able to exercise discrimination and, with less money with which to pay for them, he will assess values very carefully. This makes it all the more important not to sacrifice quality to cheapness, because we cannot afford to dishonour the tradition of good workmanship that has sold British goods all over the world.

Accurate Costing Essential

How, then, can competition be successfully met ? Only by careful estimating and accurate costing. The smaller the margin of profit the more vital it is to know exactly what the position is. It would be foolhardy to take chances with materials, when unsuspected defects could upset the most carefully calculated transaction. In the field of castings, especially, the existence of accepted standards provides means of avoiding unnecessary risks.

The meticulous control necessary to ensure conformity with specifications cannot be exercised without expense to the supplier, who has to employ qualified and experienced

supervisory staff, and equip them with costly instruments and apparatus. There are many ways in which the cost of castings could be reduced: by using lower grade metal, by relaxing control of melting and pouring temperatures, by less frequently sampling, and less vigorous inspection and testing. To the customer who does not check the quality of castings—and not all are equipped to do so—the deterioration may not at once be apparent, but will almost certainly show up sooner or later.

The Light Metal Founders Association exists to maintain, by the free interchange of technical information and by friendly co-operation, a level of quality in light alloy castings worthy of a progressive industry. Its members realize that only by doing so will they be able to develop and enlarge the fields of application of light alloys. Skimping is recognized to be short-sighted and detrimental to real progress, however keen price competition may be. For the individual founder it is far better to lose an order than to win it at the expense of reputation, and for the industry as a whole gains made in the invasion of markets hitherto held by ferrous or other non-ferrous metals cannot be consolidated if they have been won by reckless tactics. But, to some extent, founders are in their customers' hands, and if no value is set on quality control the pressure of competition may force its abandonment.

Institute of Fuel Annual Luncheon

Need of Fuel Technologists Stressed by President

THE Annual Luncheon of The Institute of Fuel was held at the Connaught Rooms, London, on Thursday, April 23rd, 1953, and was attended by some 600 members and guests.

Following the luncheon in the Grand Hall, the toast of "The Institute of Fuel" was proposed by the Rt. Hon. Geoffrey Lloyd, M.P., Minister of Fuel and Power. The Institute, he said, was one of the leading professional institutions of our country, and being relatively young it had all the vigour of youth. The status had been marked by the grant of a Royal Charter a few years ago, and lately by the acceptance by H.R.H. The Duke of Edinburgh of Honorary Membership.

The Institute ought now to acquire the appropriate "furniture" in company with other leading professional institutions by adopting a number of "worthies" from the pioneers who had in the past devoted themselves to work in the fuel field. He would like to suggest two names. The first one was Benjamin Franklin, the United States philosopher, scientist and statesman, who in his early work on fuel technology had first propounded the doctrine that smoke was a sign of inefficient combustion: British scientists were still working, notably in the design of domestic appliances, along the lines that Franklin had followed in 1785. The second pioneer, less well known but more closely connected with fuel matters, was Stanley Jevons, first Professor of Political Economy in the University of Manchester. A century ago he made some remarkable prophecies arising from a study of the rate at which our coal deposits were being exhausted and he forecast that Great Britain would be outstripped by the U.S.A. in industrial output owing to the latter's vastly greater unexploited coal resources. Jevons might be described as the father of fuel efficiency in Britain, since he had been the first to point out the necessity for husbanding our resources of indigenous fuel.

In Jevons's time the fuel consumption per head in the United Kingdom had been eight times that in the U.S.A. By about 1870, however, the U.S. coal consumption had begun to rise much faster than the British. In the early years of this century they had drawn level, and to-day the *per capita* fuel consumption in the U.S.A. was nearly twice as high as in Britain, while total consumption was about six times as great.

Another fact that was comparatively little known in this country was that whereas coal production in Russia a few years ago had been 80 million tons less than ours, now it was more than 80 million tons greater and judging by the current plans it was expected in five years' time to be nearly double that in the United Kingdom. Thus "the *new* Elizabethan age" was not a mere newspaper phrase. In terms of industrial power it was a reality. We were facing in the economic field competition from other States that had far greater fuel potential than ourselves. It would require the exercise of all the skill of our industrial scientists to meet the challenge in the next few years.

Responding to the toast, Dr. G. E. Foxwell (President) paid tribute to the work of the Ministry, mentioning especially that of the Technical Branch. Inspired by one of the Fellows of The Institute, Sir Harold Roxbee Cox, the Ministry were actively promoting, with the co-operation of great industrial organisations, the development of broad measures of immense future significance, such as the gas turbine, now finding applications on land, in power stations, in the recovery of waste heat in gasworks, at sea as well as in the air. They were investigating the heat pump, and the long-distance transport of coal water-borne in pipes; they were encouraging the development and installation of better domestic fuel appliances. By working on underground gasification the Ministry might well enable us to secure energy from such seams of coal as could not be economically mined. He (Dr. Foxwell) would like to think that they were giving attention to the utilisation of the millions of therms of natural gas wasted daily in the Middle East, by piping that gas to the industries of Europe. In all fields of fuel utilisation the Institute stood behind the Ministry. It was independent of any industry or corporation, but it served all.

One of its major objectives was to ensure that there was throughout the country, leavening the Civil Service, the professions, industry and commerce, a sufficient number of adequately trained and experienced fuel technologists. Fuel technologists might be of two categories: (1) the specialist devoting his whole energies to the professiou; and (2) the engineer, chemist, chemical engineer, electrical engineer, and so forth, engaged mainly in his major profession, but having in addition knowledge and experience of fuel technology to a standard adequate for corporate membership of this Institute.

To this end the Institute had, within these last two years or so, overhauled its educational policy. It had brought the practice of admission to membership into line with that policy. Its qualifying standard was as high as that of any qualifying body in the country. Moreover, the practice of fuel technology could not advance unless it walked with science, and the Institute was therefore greatly expanding its *Journal* to permit the inclusion of scientific papers on the subject without in any way reducing the amount of practical information published. The meetings, discussions and special conferences of the Institute were open to all, for its object was the advancement of the science and technology of the subject, wherever fuel was used.

Unless the Institute succeeded in creating an adequate body of fuel technologists, the Minister's fuel policy when it emerged would be still-born. If the Institute succeeded, the task would be accomplished. Men could devise all the policies in the world, but they would fail if the individual effort and knowledge were not behind them.

It was often said that there were too many people who were not manual workers. This was particularly urged against the nationalised industries. As so often happened, the truth was the exact opposite of popular clamour. The visit of productivity teams to America had shown us that we must employ not fewer, but many more technologists in relation to our manual workers. It was imperative that this country should secure the efficient use of its fuel, and it was only through technology that it could do so.

The Institute now had over 4,000 members. They might consider how many fuel technologists there should be if their mutual objective were to be secured, by postulating that it was worth while for a firm to employ a man as a fuel technologist if he did no more than save fuel equal in value to his salary. If the minimum saving that a fuel technologist could make was 10% of the fuel consumed, roughly he might be said on this (admittedly inadequate) criterion to be worth £300 per 1,000 tons of fuel used a year.

There were in this country :—

658 firms each using over	10,000 tons of coal a year.
1,005 firms each using 4,000 to	10,000 tons of coal a year.
1,550 firms each using 2,000 to	4,000 tons of coal a year.

That is, 3,213 firms who could use one or more specialists of Category (1). There were also 10,000 firms using 300 to 2,000 tons annually, each of which should have one part-time fuel technologist from Category (2). Adding these up and including the Civil Service, consultants, other professions and the nationalised industries, he got a minimum of 4,000 specialists (Category 1) and about 12,000 of Category (2)—a total of 16,000.

They had thus a long way to go, but he thanked the Minister for the encouragement he had given them on their journey. In their efforts to promote improved production and utilisation of fuel, this Institute would march behind him ; and even sometimes in front of him !

New and Revised British Standards

Free Machining Brass Rods and Sections (B.S.249 : 1953), Price 3s.

In this revision the range of sizes covered has been extended to include material $\frac{1}{16}$ in. diameter, the chemical composition has been slightly altered, and rolled material has been omitted, as the type of material covered is now generally extruded or extruded and drawn. Tolerances have been amended, to bring them into line with present day practice. Throughout the standard, the term " rod " has replaced the term " bar " which was used in the 1940 edition, as in accordance with the definitions of B.S.1420 " Glossary of terms applicable to wrought products in copper, zinc, brass and other copper alloys," " bar " refers to material of thickness over $\frac{3}{8}$ in. and up to and including 12 in., whereas " rod " has a more general application.

Copper for Electrical Purposes. Sheet and Strip (B.S.1432 : 1953), Price 4s.

This revised edition is one of a series of standards for copper for electrical purposes. The others in the series are :—

B.S.1433—Copper for electrical purposes. Bar and rod.

B.S.1434—Copper for electrical purposes. Commutator bars.

B.S.0000—Copper for electrical purposes. Tubes (Shortly to be published).

The principle feature of this revision, which includes provisions for annealed, half hard and hard conditions, is the introduction of two diagrams of recommended sizes of sheet and strip for transformer windings and the windings of rotating electrical machinery respectively from which designers are encouraged to choose their requirements. It is hoped in this way that there will in time be a considerable reduction of the number of sizes demanded. An additional provision is included in this standard whereby the purchaser can, by special arrangement, specify that sheet or strip shall be made from oxygen-free high conductivity copper complying with B.S.1861 (recently published).

Aluminium Filler Alloys for Brazing (B.S.1942 : 1953), Price 2s.

This new British Standard is complementary to B.S.1723, " Brazing," and to B.S.1845, " Filler alloys for brazing (silver solders and brazing solders)." The standard covers four types of aluminium alloy suitable for brazing a number of alloys complying with the series of British Standards for aluminium and aluminium alloys, namely B.S. 1470 to 1477, and 1490. Chemical composition and limits of impurities together with the form of material are specified, and the approximate melting ranges are given for information.

60/40 Brass Rods, Sections and Forgings, Etc. (B.S.1949 : 1953), Price 3s.
Copper-Silicon Alloy Rods, Sections and Forgings, Etc. (B.S.1948 : 1953), Price 3s.

Each Standard specifies requirements for rods and sections of diameter not less than $\frac{1}{16}$ in. and for forgings in the alloy, with regard to chemical composition and mechanical properties. It also includes tables of tolerances on round, square and hexagon rods.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 24, Victoria Street, London, S.W.1.

Coal Gas and Aluminium

IN February, 1948, an aluminium roof was installed over the dry purification plant at Sevenoaks, Kent, Gas Works. This was an experiment that the South-Eastern Gas Board were making to ascertain the suitability of aluminium as a structural material in gas works, and the purifier was chosen because the severity of the conditions of exposure was known. So successful has the experiment been that the South Eastern Gas Board have recently erected other aluminium roofs at their works at Wandsworth and Guildford.

The roof was built by the Aluminium Construction Co., Ltd., using standard structural sections with corrugated sheet covering. The metal was supplied by Northern Aluminium Co., Ltd., the alloys being Noral 51S for the sections and Noral 3S for the sheet—H10 and N3, respectively, in the British Standards designation system. No paint or other protection was applied.

The aluminium roof over the gas purifier at Sevenoaks Gas Works at the time of its erection. In spite of the severely contaminated atmosphere the roof is in excellent condition after five years.

Now, after nearly five years, the condition of the roof is apparently unimpaired, though it has lost its original brightness: this change in appearance took place during the first year or so. Superficial examination reveals roughening of the surface of the metal and slight pitting, but there is no evidence of appreciable deterioration. To verify the apparent soundness of the roof the South Eastern Gas Board arranged with Northern Aluminium Co., Ltd., to remove a structural member and a sheet, and have them subjected to laboratory examination. This has been undertaken by Aluminium Laboratories, Ltd., and confirms that the corrosion is very slight.

Examination After Four Years

The specimens were taken in January, 1952, after nearly four years' exposure. Metallurgical examination revealed pitting corrosion of the structural member to a maximum depth of ·0173 in. and a mean depth of ·0063 in. The thickness of the section being $\frac{1}{4}$ in. on the flanges and $\frac{3}{16}$ in. on the web, this penetration is insufficient to affect the strength appreciably, as was proved by tests which showed that the tensile properties still exceeded the minimum figures required by B.S.HE10, on which the design of the structure was based. On the sheet specimen, which was ·028 in. thick, there was pitting to a maximum depth of ·0047 in. on the inner surface; the outer surface showed only very slight superficial corrosion. Tensile tests confirmed the soundness of the sheet, the figures obtained being well above the minimum demanded by B.S.NS3.

Type of Corrosion

Research extending over many years has shown that the main type of attack to which aluminium alloys are subjected on exposure to aggressive atmospheres is by pitting, pits being formed at the points at which the protective oxide film, characteristic of aluminium alloys, is weakest. Though the onset of pitting corrosion may be rapid, as the points of weakness are taken up, the rate at which new pits form must diminish. Moreover, under many conditions of exposure a new oxide film is formed, which prevents further attack.

Pits may be deep—"pinholes"—or broad and shallow: the degree of deterioration is indicated by tensile tests. Figures showing loss of strength plotted on a time base form an exponential curve; and a fairly short time from commencement of exposure most of the corrosion that is going to take place will have done so. The period varies with the metal and the conditions of exposure, but usually deterioration of these particular alloys after 3–4 years will be very slow.

The sampling in this case was, therefore, well timed, and the results of the laboratory examination and tests provided a clear and reliable pointer to the durability of the roof, which can confidently be expected to remain serviceable for more than 25 years. This period is chosen as representing the expectation of life of a galvanised steel roof, carefully maintained and painted every two years.

The Economic Aspect

On technical grounds there is a case for the use of aluminium under such conditions, but the first cost of an aluminium roof would be some 75% dearer than a similar roof in galvanized steel. On the other hand, repainting of a steel purifier roof is found to be necessary every two years, although for less severe conditions an interval of four years may be permissible. Assuming a roof life of 25 years, the total cost of a steel roof painted every two years would be almost double the cost of an aluminium roof which required no painting, and even with only 6 paintings in the 25 years, the steel roof would still cost more.

The results of these technical considerations and an examination of the economic aspects suggest that there are likely applications for aluminium in the environs of gas works, and that consideration should be given to its adoption for the roofing of industrial buildings wherever the atmosphere is sulphur-laden or polluted with products of combustion.

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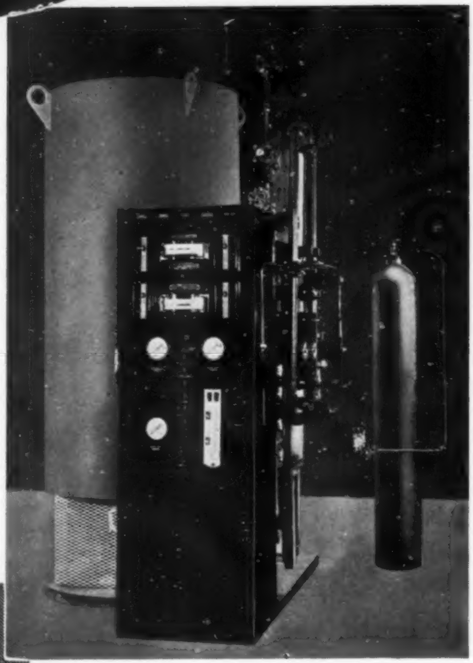

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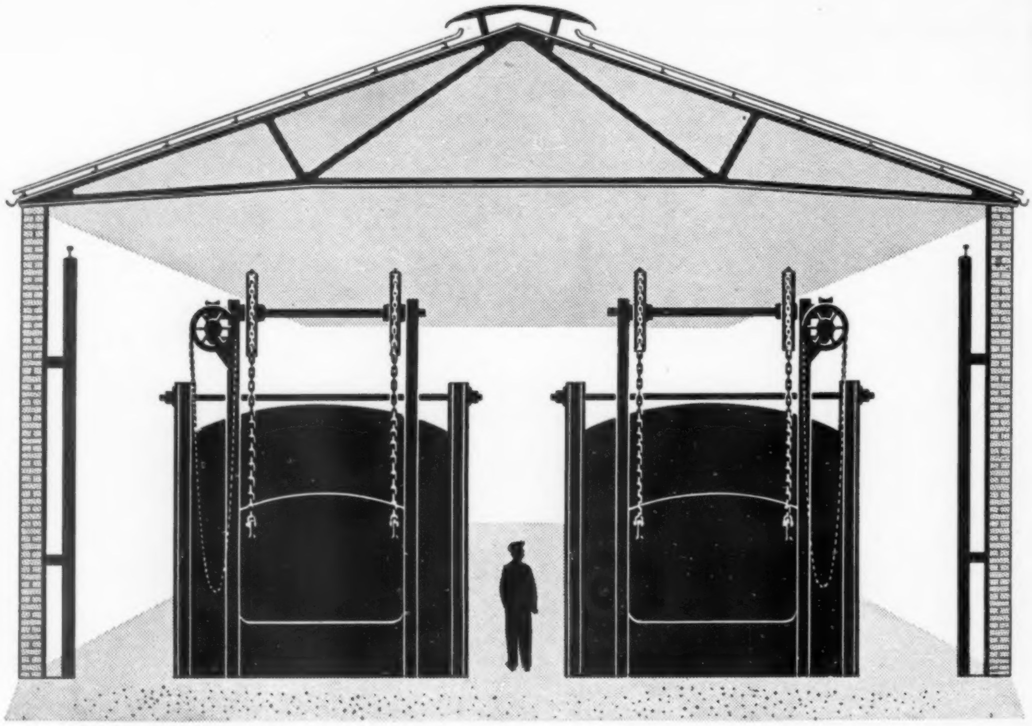

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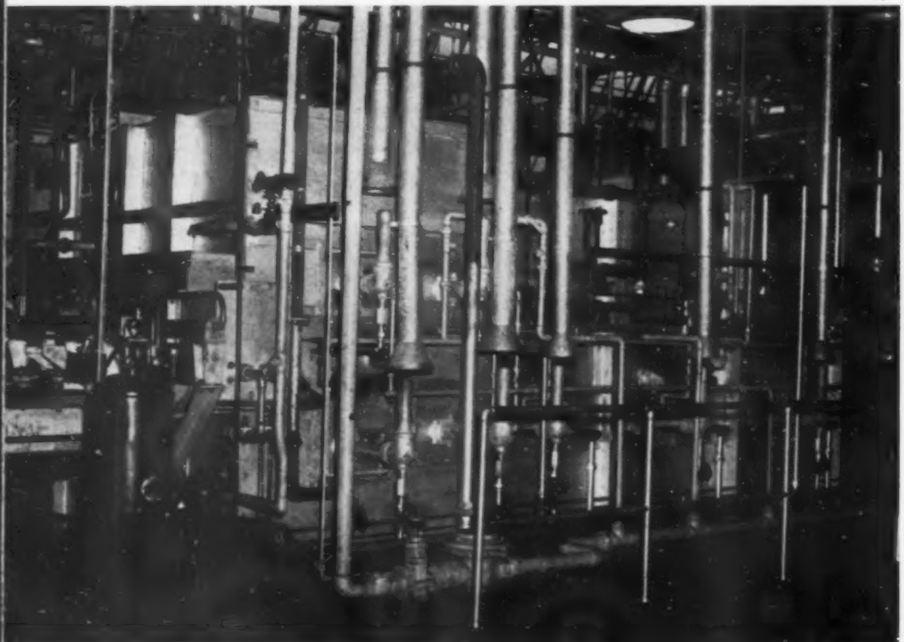

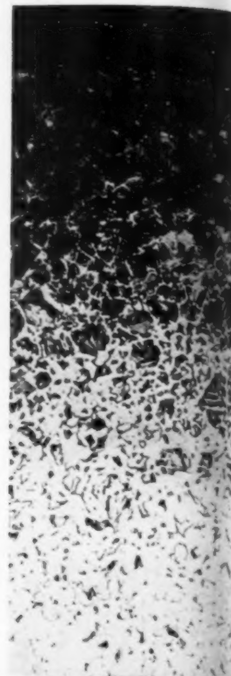

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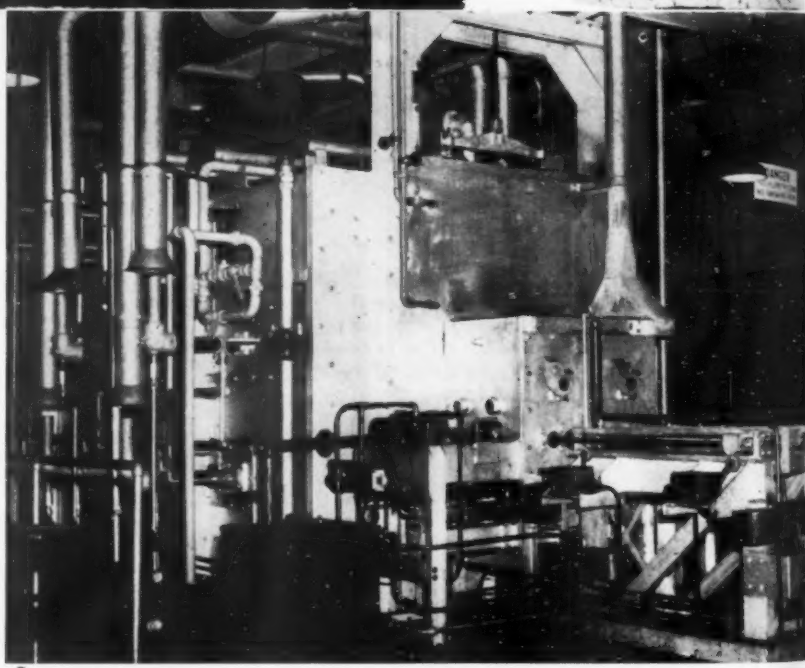

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Heat-Treatment Furnace Developments
Recent Installations for Ferrous and Non-Ferrous Metals

Progress in the design of heat-treatment plant in the last few decades has contributed in no small degree to the great advances made in the manufacture of high-grade products. To-day the heat-treatment furnace is more nearly a precision tool, and although the changes effected at relatively short intervals may not be great, this review of some recent installations shows that progress is continuous.

HEAT treatment of one sort or another is associated with practically all the operations involved in converting ores into finished metal components, but in this article attention is confined to plant for heating solid metals. In the main, it concerns plant for heat-treatment operations which produce in the material the final structure required in the completed component, or which make it easier to work, but reference is also made to installations for reheating before hot working. Additional refinements may also be desirable, such as a bright or clean finish on the material treated, in which case scaling, decarburisation, and other chemical reactions must be eliminated from the heat-treatment process. Such refinements often have economic advantages since they may entirely overcome the need for secondary cleaning operations. It will be appreciated, however, that satisfactory results in achieving the main objective depend upon the equipment, the material or component to be treated, and those responsible for carrying out the operations.

Many factors are involved in the design of furnaces, whether for reheating, annealing, stress relieving, carburising, hardening and tempering, malleabilising, etc., and the value of the result has an important influence in determining the type. The main considerations involved are the quality of the finished product or component and its overall cost, and other factors involved, such as the heating medium employed, temperature and atmosphere control, and other heat-treatment operations should be studied in relation to these considerations. Limitation of space may have to be considered in designing heat-treatment equipment for a particular works. Thus, it is important to keep in mind the need for producing a high-grade product at low cost, using that form of heating medium and that type of equipment which will give these results under the conditions that operate in the works at which the installation is contemplated. In some cases the actual cost of heat units used is secondary to the essential need for the attainment of the required standard of quality of product, since the cost of failure to satisfy this standard consistently far outweighs the slightly higher cost of energy consumed and the capital charges involved in the provision of more complicated equipment. This does not mean that economy in the use of heat energy can be disregarded, but it does mean that in special cases there is a standard of accuracy of temperature and uniformity, a degree of reliability and ease of control, that may not be attainable except with the most refined and elaborate methods.

Although improvements in design of furnace equipment over relatively short intervals may not be great, there is ample evidence that progress is continuous. Some of these are associated with several recent installations and will be referred to later in this review, but mention may be made here of the attention which has been given, particularly in recent years, to heat recovery, with a view to achieving higher overall efficiency. The increasing cost of fuel has caused builders and users of furnace equipment to apply the principle of heat recovery to effect economy in fuel and/or accelerate the speed and reliability of the operations in hand. Clift and Knight[1] have described important features of both direct and other forms of heat recovery in industrial furnaces in an article in which they refer to the development of a unit, employing a gas with a calorific value of only 300 B.Th.U./cu. ft., which used a refractory recuperator for preheating the combustion air. Its purpose was to preheat tube or bar in a continuous flow line for further processing. Temperatures up to 1,800° C. in the heating chamber were made possible by air preheats of about 1,000° C. As the stock needed to be brought up to only 1,000° C., the heating rate was extremely fast, and furnace scaling was negligible.

The authors state that most furnaces working on lean fuels, where high operating temperatures and rapid concomitant heating rates are required, must have some form of direct heat return, sometimes to both gas and air. Examples are to be found in soaking pits; using mixed clean gas without preheat they would be expected to develop temperatures of about 1,000°–1,100° C., but with preheat of air and gas, temperatures of 1,350°–1,400° C. may comfortably be reached.

Types of Furnaces

Whatever heat-treatment process it is desired to carry out, the types of furnaces used may be broadly classified as batch, semi-continuous, or continuous furnaces. The batch type, with or without a removable charge container, was developed first, although, apart from the box-type heating chamber, there is no real comparison between the modern batch-type furnace and the early designs. Because of their adaptability for the treatment of products varying widely in size, quantity, and even type of treatment, batch furnaces will always be popular. Variations from this type arose with the standardisation of products or components: thus, as the quantity of a particular product, requiring the same treatment, increased and became a fairly constant requirement, the need for furnaces in which material or components to be treated could be automatically handled brought about the continuous heating and cooling operations. In addition to temperature control, and in many cases atmosphere control, some

[1] A. Clift and C. Knight, *J. Iron and Steel Inst.*, 1952, **172**, 327-339.

Courtesy of The Wellman Smith Owen Engineering Corporation, Ltd.

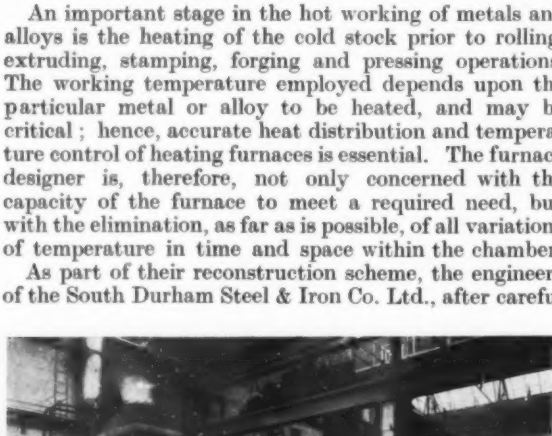
Fig. 1.—Bottom-fired soaking pits recently installed at the West Hartlepool Works of the South Durham Steel and Iron Co., Ltd.

modern furnaces have time-cycle control and are designed to repeat accurately a required treatment with a view to obtaining a uniform product. Between the batch and continuous furnaces there are various intermediate designs which can be regarded as semi-continuous. Some examples from recent installations of these types for varying treatments are briefly described in the following notes.

Reheating Furnaces

An important stage in the hot working of metals and alloys is the heating of the cold stock prior to rolling, extruding, stamping, forging and pressing operations. The working temperature employed depends upon the particular metal or alloy to be heated, and may be critical; hence, accurate heat distribution and temperature control of heating furnaces is essential. The furnace designer is, therefore, not only concerned with the capacity of the furnace to meet a required need, but with the elimination, as far as is possible, of all variations of temperature in time and space within the chamber.

As part of their reconstruction scheme, the engineers of the South Durham Steel & Iron Co. Ltd., after careful consideration, decided that the bottom-fired type of soaking pit would be the most economical and efficient and, therefore, installed the two pits shown in Fig. 1 in their existing soaking pit bay. The recuperators are built alongside the pits and underneath the operating platform on which is located the instrument house.



Courtesy of Birlec, Ltd.

Fig. 2.—Gas-fired walking beam furnace for heating copper wire billets.

The output specified from the two pits was 5,000 tons/week of 136 hours, based on 83% hot ingots, having a track time of 2 hours, and 17% cold ingots. This output has been maintained and exceeded. The pits are arranged in a single row, each pit being 18 ft. long, 17 ft. wide and 11 ft. deep, capable of holding a charge of 120 tons, comprising eight 15-ton ingots. The average charge of the pits is 100 tons when heating 7- and 10-ton ingots. This size was decided upon because it would take half the cast from the 200-ton tilting open-hearth furnace. The pits are fired with blast-furnace gas of 95 B.Th.U./cu. ft. and are supplied with a metallic gas preheater in addition to a refractory air recuperator. The average fuel consumption is 900,000 B.Th.U./ton, but when heating hot ingots the fuel consumption does not exceed 600,000 B.Th.U./ton.

Courtesy of The Wellman Smith Owen Engineering Corporation, Ltd.

Fig. 3.—A continuous billet heating furnace installed at Round Oak Steelworks, Ltd.

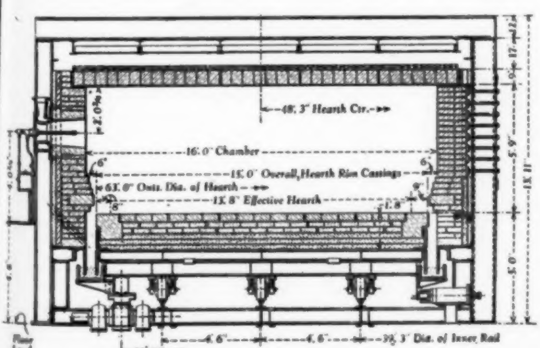
The single port located in the bottom of each pit permits complete combustion of the gases without their impinging on the ingots. Although provision was made for these pits to operate with a 12-in. coke breeze bottom, they have proved very efficient and economical with a solid chrome bottom, which does not require any renewal over a period of six months. The waste gases, which are removed through equally-spaced ports near the base of the pit end walls, are collected in a flue which runs from the pits across to the underside of the recuperator, where they flow vertically through the inside of thin-wall refractory tubes which have high conductivity and low porosity. The air, which is supplied by a fan, enters the top of the recuperator and flows around the tubes in a shuttle path and is collected into a flue which runs direct to the base of the concentric venturi-type pressure gas burner. The exhaust gases from the air recuperator flow through a metallic tubular gas preheater. The air preheat temperature averages 950° C. and the gas preheat temperature 300° C. The final exhaust gases flowing to the chimney have a temperature of 450° C. These pits are completely

instrumented, the automatic system of control comprising temperature control, combustion control, and pit-pressure control.

The continuous walking beam furnace, shown in Fig. 2 and recently installed at the Forge Lane works of Richard Johnson and Nephew, Ltd., is for heating copper wire bars prior to hot rolling. It has two parallel tracks, overall width over the two tracks being 9 ft., and heated length 50 ft. Output is 15 tons/hr. of copper heated to 900° C., for a consumption of 30,000 cu. ft./hr. of town's gas.

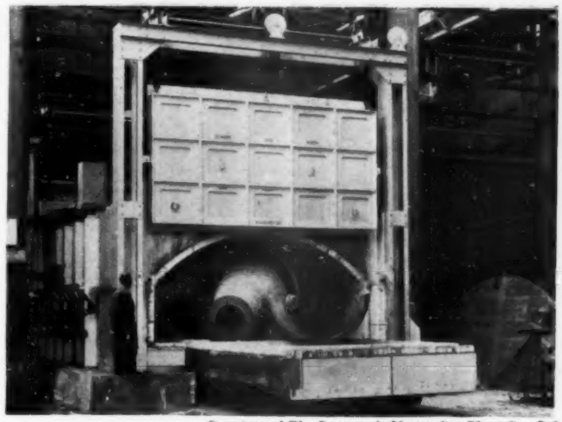
Heating is by open burners, and arrangements are included for precise combustion-ratio control, at all input rates, which, in conjunction with suitable sealing devices, ensures that the furnace atmosphere may be maintained oxidising, neutral or reducing at will. Four high-speed circulation fans are located along the length of the roof to improve the heating rate and temperature uniformity. Mechanical operation is almost entirely automatic, billets being charged on a loading conveyor, whence they are removed by mechanically-operated arms on to driven diabolo roller tracks feeding, through side openings in the furnace, the two furnace tracks alternately. At the discharge end, transfer is again automatic from the furnace tracks through side wall openings directly on to the mill feed table.

Recently installed at Round Oak Steelworks, Ltd. is the continuous billet heating furnace shown in Fig. 3, with a hearth length of 52 ft. and a width of 18 ft. It has an output of 20 tons/hr. of billets ranging from 2½ to 6 in. square and in lengths varying from 7 to 16 ft., based on heating the billets from cold to 1,250° C. The furnace has three zones—one soaking zone, which has five Basequip burners, and two heating zones, one over and the other under the billets. Each of the two heating zones has four Basequip burners located in the side walls of the furnace. These burners are of the air-pressure type having no projections or small apertures in the path of the gas stream. The turn-down ratio of the burner is approximately 5 to 1, which is a useful feature should the furnace require to be held at temperature in the event of hold-ups on the mill. The furnace is fired with raw bituminous gas of 150 B.Th.U./cu. ft. and mushroom-type valves control each group of burners in each of the three zones, in addition to the mushroom-type valve controlling each individual burner. These burner gas valves have sand seals which permit expansion in



Courtesy of Engineering and of Salem Engineering Co., Ltd.

Fig. 4.—Section through a rotary hearth furnace for heating blooms prior to slabbing for making railway wheels.



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 5.—Gas-fired plate heating furnace.

every direction. Due to the method of zoning, roof contour and high air preheat temperature, this furnace has a thermal efficiency exceeding 45%.

Exhaust gases from the furnace are collected in a flue which conveys them to a refractory tubular recuperator, where the gases flow vertically through the inside of the tubes and the air to be preheated flows around them and is finally induced by a hot air fan, ensuring the supply of air at a pressure of 4–6 in. W.G. and a preheat temperature of 350° C. at the burners. The recuperator is equipped for automatic control.

Believed to be the largest in Europe is a rotary-hearth furnace installed at the Trafford Park Steel Works of Messrs. Taylor Bros. & Co., Ltd. as part of a new plant for producing rolled-steel solid wheels and disc centres for railway carriages and wagons. The new plant is designed to produce wheels ranging from 24 to 50 in. diameter on the tread at a continuous rate of 60 pieces/hr. The furnace has a rated heating capacity of 40 tons of steel per hour at a maximum temperature of 1,280° C. The diameter over the outer buckstays is 69 ft. and the hearth is 15 ft. wide with a hearth centre diameter of 48 ft. 3 in. A sectional elevation, showing the construction, is shown in Fig. 4. Blooms, to be slabbed, forged, punched and rolled to form the wheels, are fed to the furnace by gravity roller conveyor and then by a furnace charger. The charger picks up the blooms individually and places them in radial rows on the hearth of the furnace. The blooms pass successively through preheating, heating and soaking zones in the furnace and are then taken individually by a furnace discharging machine to a transfer car. This car transfers the bloom through a hydraulic descaling machine to an 8,500-ton hydraulic press.

This furnace, built by the Salem Engineering Co., Ltd., has four firing zones and is fitted with 39 steam atomising burners designed for burning heavy fuel oil. Preheated air for combustion is obtained by using part of the heat contained in the waste gases, two Newton Chambers needle-type metallic recuperators being used as heat exchangers. The hearth, which is of the Salem floating type, is carried on 108 wheels fitted with taper-roller bearings running on circular rails. The furnace hearth permits a maximum of 371 blooms to be charged, which are carried through the heating and soaking zones, by progressive indexing of the hearth, at a rate corresponding to the output of the plant. At a production rate of 60

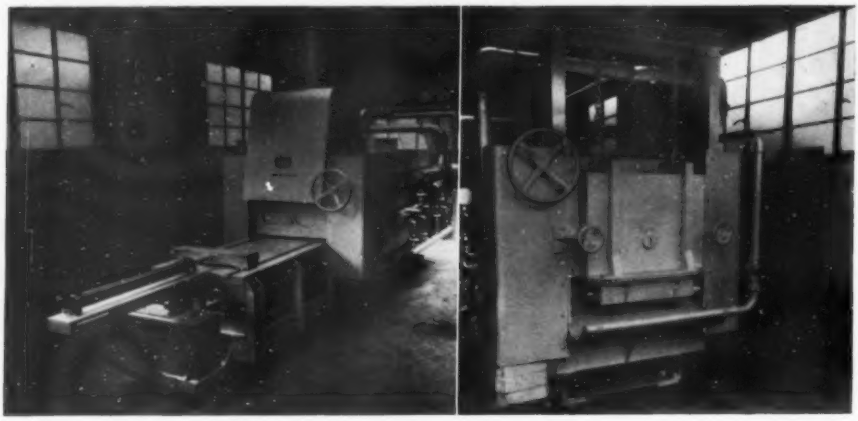


Fig. 6.—The charging and discharging ends of a high-speed heating forge furnace for heating Nimonic blanks prior to stamping. The charging end is fitted with a hydraulic pusher.

Courtesy of Thermic Equipment & Engineering Co., Ltd.

pieces/hr. the heating time of the blooms is about $6\frac{1}{2}$ hours. The furnace is equipped with Honeywell Brown "Electronik" temperature controllers and Electroflo fuel/air ratio controls in each zone, and with Electroflo automatic furnace pressure control operating on the recuperator dampers.

Although the furnace shown in Fig. 5 was designed specifically for plate heating, the temperature distribution and flexibility of operation over a wide range of temperature has enabled it to deal with stress relieving, annealing and other heat-treating cycles when existing furnaces for these purposes are working to capacity. The furnace shown has a working space 14 ft. wide × 30 ft. long × 6 ft. 6 in. high from bogie to crown, with doors at each end. It is heated by 16 Min-O-Max automatic proportioning town's gas burners. Electrically-operated bogie-moving mechanism installed in a pit facilitates the rapid handling of heavy plates. Easy operation of the burners by adjustment of the air supply only, and the effective sealing of the doors and bogie contribute to the high thermal efficiency and quick response to heat demands called for in a furnace of this type.

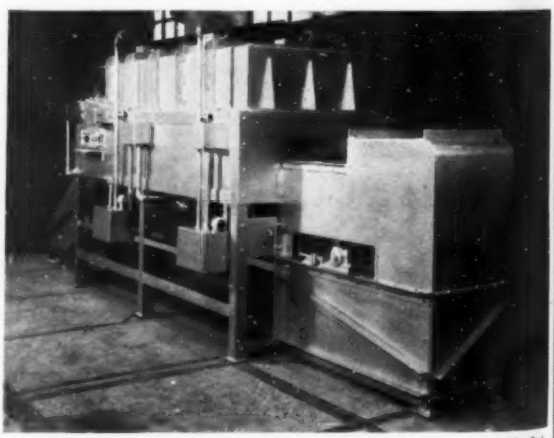
Fig. 6 shows the charge and discharge ends of a gas-fired high-speed heating furnace designed for an output of 15 cwt. of Nimonic blanks per hour for the stamping of turbine blades. It has an effective hearth area of 8 ft. × 18 in. and is fired by a series of Thermic CC burners for rapid heating. The whole furnace is mounted on shock absorbers so that high-frequency shockwaves are eliminated from the furnace brickwork, thus greatly increasing the life of the furnace refractories.

High-speed heating is a recent development in this country and America. Practical tests have demonstrated that steels which have been subjected to high-speed heating are capable of greater plastic deformation for a given rolling pressure than steels heated by normal methods. The outstanding feature of high-speed heating is that the furnaces operate at temperatures as high as 1,650° C., and as the amount of heat transmitted by radiation varies as the fourth power of the absolute temperature, the rate of heating is greatly increased; further, the steel is at scaling temperature for the minimum amount of time.

A high-speed heating furnace may be a small, self-contained unit with a heating chamber approximately 3 ft. long by 2 ft. wide. To obtain the required output, a number of these units may be placed in tandem line with the mill. A continuous plant of this type is being installed by the Incandescent Heat Co., Ltd. in the Sheffield area for heating mild, high-carbon, stainless, chromium and silicon steel slabs. The system of firing is by concentrated combustion burners which operate on town's gas. Air for combustion is preheated to 400° C. by recuperators and supplied at a pressure of 2 lb./sq. in. The plant will have an output of 10 tons/hr. when heating slabs $1\frac{3}{4}$ in. thick by 15 in. wide.

For heating aluminium-bronze blanks prior to forging, the electrically-heated furnace shown in Fig. 7 has been designed. It is a continuous chain-conveyor-type furnace with a heating length of 6 ft., having an output of 200 blanks/hr. at a temperature of 950° C. The blanks are conveyed through the heating section longitudinally and reach the operating temperature in approximately 20 minutes from cold. The conveyor gear comprises a pair of chains carrying heat-resisting steel carriers, pitched at $4\frac{1}{2}$ in., each arranged to hold eight blanks across the width of the chamber. The conveyor is of the intermittent drive type operated by a push button starter and stop switch.

The use of mains frequency induction heaters for non-ferrous billets and slabs, particularly light alloy billets for extrusion, has developed in the United States and favourable reports on their operation have induced a number of British manufacturers to work on this method.



Courtesy of Brayshaw Furnaces & Tools, Ltd.

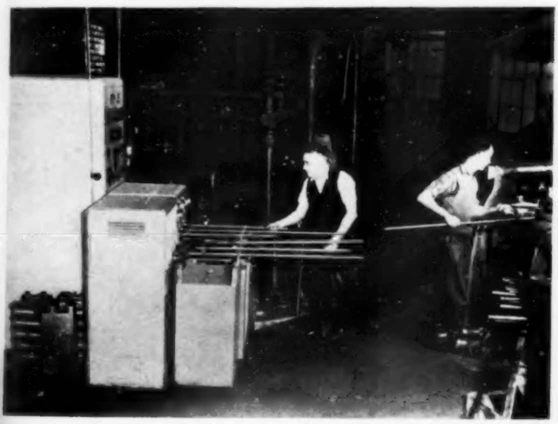
Fig. 7.—An electrically-heated continuous chain conveyor type furnace for heating aluminium bronze blanks prior to forging.

Birlec, Ltd., for instance, reports three units under construction, one for brass billets for extrusion (2½ tons/hr.), a second for aluminium slabs for rolling (1 ton/hr.), and a third for aluminium alloy billets for extrusion (¾ ton/hr.).

High-frequency induction methods are also used for heating stock prior to hot working and Fig. 8 shows an installation at the works of Trojan, Ltd. The station is provided with three horizontal helical inductor coils permanently connected across the output terminals of a 30 kW 10,000 cycle generator. Bars ¾ in. diameter are inserted into the three coils in sequence and are removed after a predetermined heating time ready for insertion into the machine for upsetting and cropping. The next bar is then removed and replaced by that just cropped, the inductor coils being specially graded to allow for the temperature gradiant at the end of the bars after cropping. New bars are inserted into one of the three coils of an adjacent station which are permanently connected to the 30 kW generator but take only some 5-6 kW. These coils produce the same temperature gradient as exists in a bar after upsetting and cropping, and bars may be left in them indefinitely until required. The complete equipment has an output of 125 10-in. heated lengths per hour.

Annealing Furnaces

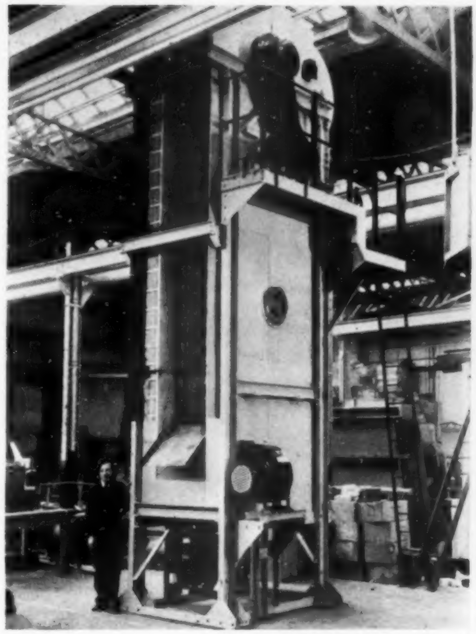
Continuous furnaces of the conveyor type usually require considerable floor space; when floor space is restricted, however, modifications in design must be made in order to adopt the conveyor principle. The vertical conveyor furnace shown in Fig. 9 is a recent example. It was necessary to design a vertical furnace with a base measuring only 5 ft. 6 in. by 6 ft. 3 in. The total height is 21 ft. 3 in.



Courtesy of Electric Furnace Co., Ltd.

Fig. 8.—Equipment for H.F. induction heating the ends of bars prior to upsetting.

This furnace is used for annealing small brass pressings, such as lamp bodies, and the components are carried upwards in pans attached to a chain conveyor at each side. On the upward journey the components are heated by a removable-plug-type heater battery, situated on the top of the equipment, giving a maximum operating temperature of 450° C., although for normal working the temperature is in the region of 350° C. The journey downwards, on the opposite side of the furnace, is used for cooling the charges with cold air induced into the chamber by means of the centrifugal fan shown on the bottom right hand side of the furnace. This equipment is located directly in the production line so that the components are fed on to the conveyor charge baskets and discharged automatically.



Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 9.—A vertical conveyor furnace for annealing small brass pressings. The total height is 21ft. 3in.

To meet the need for high production, as a result of the introduction of continuous strip rolling, the tower furnace was developed. Drever tower furnaces handle ferrous and non-ferrous strip in widths varying from ½ in. to 38 in. at rates from 100 lb. to 15 tons/hr. In certain applications they can handle as many as seven strips, each 7 in. wide, at the same time. The operation line of a Drever vertical tower strip furnace comprises an uncoiler, a seam spot welder, a gas-tight furnace and cooling chamber, pinch rolls and a recoiler. These furnaces may be heated either by electrical elements or by radiant tubes. For bright annealing, a protective atmosphere is necessary—the type of atmosphere being governed by the material undergoing treatment. For annealing brass, pickling equipment is incorporated in the line. This equipment is manufactured in Great Britain by The Incandescent Heat Co., Ltd.; the furnace shown in Fig. 10 is rated at 360 kW and has been installed for annealing non-ferrous alloys at the rate of 6,000 lb./hr.

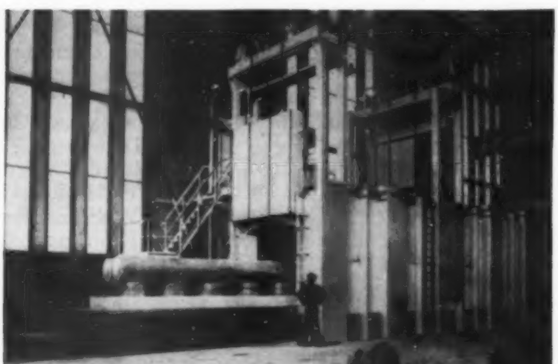
Recently installed at De Rotterdamsche Mij. N.V., Rotterdam, is a large bogie furnace for heat treating ships' propeller shafts in both forged and machined conditions. A special feature of this furnace is that it is fitted with a dividing door and split bogie, which allows the unit to be used either as a complete bogie hearth furnace or to be sub-divided and used as two separate, individually controlled furnaces. The normal load on the full length of the bogie is approximately 100 tons. The overall size of the furnace is 60 ft. by 8 ft. wide

Courtesy of The Incandescent Heat Co., Ltd.

Fig. 10.—The charge end of a 360 kW vertical strip annealing furnace for annealing non-ferrous alloys at the rate of 6,000 lb./hr.

by 7 ft. high. It has a total connected rating of 2,300 kW and the heating chamber is divided into 15 separately controlled heating zones. Fig. 11 shows a general view of the furnace with the bogie partially withdrawn.

Batch annealing of brass wire coils sometimes involves fairly drastic pickling. To overcome this difficulty a leading manufacturer of non-ferrous wire has installed the continuous annealing furnace shown in Fig. 12. The uniformity of annealing obtained has resulted in a substantial reduction in the amount of scale formed on the wire, which is removed by flash pickling. This has resulted in a saving of time and of metal losses. The furnace has an output of 600 tons of wire per week and replaces three large batch-type furnaces, with a saving of 50% in labour costs against the same output.



Courtesy of Metalectric Furnaces, Ltd.

Fig. 11.—A divided bogie hearth furnace for heat-treating ships' propeller shafts in both forged and machined conditions.

A new installation recently completed by the General Electric Co., Ltd. for annealing copper strip in coils consists of a 270-kW furnace with a number of containers, each 3 ft. in diameter and 10 ft. deep, and a recuperator pit. The furnace treats coils of copper strip weighing up to 3 tons in a cracked regenerated burnt ammonia atmosphere. To minimise the overhead height required, the furnace is sunk to ground level.

In the past, it was generally considered that recuperation was hardly worthwhile at low temperatures, but, in this latest G.E.C. installation, it is proving quite successful. The fan in the recuperator pit transfers heat from the hot container to the adjacent cold one. The fan in the hot container transfers heat from the charge and in like manner the fan in the cold container transfers heat, being received via the recuperator fan, from the envelope to the cold charge. In this way one pot is cooled and the heat taken from it is used to preheat another pot.

Recent installations for the rapid and accurate low temperature treatment of aluminium alloys include two elevator-type air recirculation furnaces—one gas heated and the other electrically heated. These furnaces are employed for solution treating and annealing aluminium alloys and are complete with work tray, pit-type quench tank, loading rack and rails above the quench tank, the bottom of each furnace being in the form of a retractable

Courtesy of Metalectric Furnaces, Ltd.

Fig. 12.—A continuous furnace for annealing brass wire. It has an output of 600 tons of wire per week.

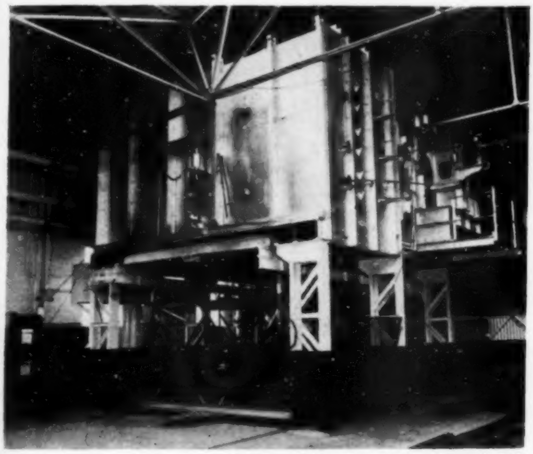
carriage to permit rapid vertical quenching of the treated work. The gas-heated furnace is shown in Fig. 13.

The system of recirculation employed to heat the stock chamber is a development of the makers in which the heater unit is entirely separate from the furnace proper and incorporates a recirculating assembly. In the gas-heated furnace, hot gases generated in the separate combustion chamber are directed through a heat interchanger which, in turn, imparts its temperature to the main volume of air being continuously recirculated in a closed system through the stock chamber, via the connecting ducting and fan assembly.

Three furnaces are shown in Fig. 14, which were recently installed at the Brierley Hill Works of Richard Thomas and Baldwins, Ltd., for the final 1,100° C. annealing of high grade electrical steel sheets of the grain-oriented type. All three furnaces are of the

elevator type with charge space cross-section of 3 ft. × 3 ft.; two of the furnaces, each rated at 240 kW, have a charge space length of 8 ft., the third, rated at 275 kW, is 10 ft. long. The latter accommodates a net charge of 13¾ tons. Each furnace has four charge bogies and four cooling stations equipped with suitable cooling hoods, and a suitable rail system permits a bogie discharged from the furnace to be transferred to any one of these stations. Special attention has been paid to furnace gas-tightness, and the atmosphere, of controlled composition and humidity, is derived from ammonia crackers and burners.

An essential feature of the new Steel Company of Wales tinplate works at Trostre is the annealing plant,



Courtesy of Brayshaw Furnaces & Tools, Ltd.

Fig. 13.—Gas-fired elevator type air recirculation furnace with provision for vertical quench.

whose purpose is the removal of the effects of the cold work imparted during cold reduction in the tandem mill and the recrystallisation of the severely distorted grain structure. The annealing unit employed (Fig. 15) is of the direct oil-fired portable cover type, twelve bases, 28 ft. 6 in. × 17 ft. 6 in. overall, being served by 5 furnace covers. Each base has 8 annealing hearth plates arranged in two rows of 4, the coils being loaded on the hearth plates up to a maximum height of 132 in. with convector plates between each coil. Each stack of coils is covered with a protective inner cover of 10-gauge 18:8 stainless steel. The protective atmosphere (N.X. gas), which is generated from kerosene burned without excess air, reaches the coils through an aperture in the hearth plate and is circulated round the coils by means of a fan located just below this aperture. The furnace cover, which is 28 ft. 6 in. long × 19 ft. wide × 15 ft. 3 in. high, has 14 air-atomised oil burners on each side and one at each end. A central row of 3 exhaust ports arranged between the hearths takes the products of combustion to the flues in the basement. The oil feed is by two 4 h.p. pumps delivering through a ring main. Maximum fuel consumption of each furnace is approximately 67 gal./hr. of gas oil of 19,600 B.Th.U./lb.

The continuous bright annealing furnace shown in Fig. 16 is of particular interest since it is one of a number of installations for bright annealing pressings in which the fuel employed is liquified petroleum gas. This furnace has an overall length of 33 ft. 7 in. with a

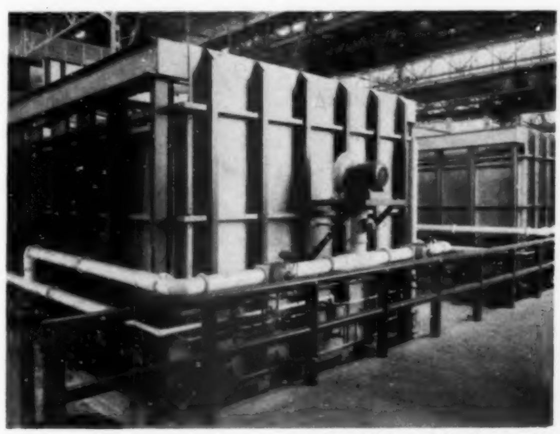
Courtesy of Birlec, Ltd.

Fig. 14.—An elevator furnace for annealing electrical sheets.

heated zone 6 ft. long. It has a woven wire conveyor belt 12 in. wide and was designed to anneal various metal pressings at temperatures ranging from 650° C. to 1,020° C. A variable speed gearbox drives the conveyor belt over pulleys whose faces are treated to give a good gripping surface, the discharge pulley being pressure loaded as a further precaution against belt slip and to ensure smooth transmission.

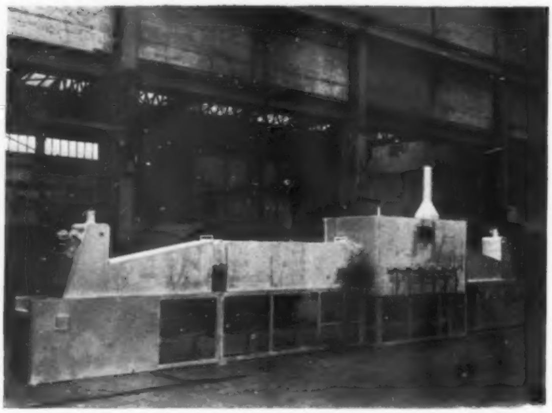
A continuous stainless steel sheet annealing furnace is shown in Fig. 17. It is a muffle furnace fired by Eddy Ray town's gas burners and operates at 1,120° C. inside the muffle. The work to be treated is carried through the muffle by an overhead conveying system having alloy steel charge hooks and sealing plates.

An electrically heated continuous type furnace for annealing aluminium-bronze blanks at the rate of 400/hr. has recently been supplied by Brayshaw Furnaces and Tools, Ltd. The heating elements are arranged in two zones for heating and soaking, the blanks entering the work chamber at a temperature of 400–500° C., being soaked for one hour and discharged at 700° C. In this furnace, the hearth is of Carborundum material, with heat-resisting steel skids to guide the work trays through the furnace chamber. The work



Courtesy of Salem Engineering Co., Ltd.

Fig. 15.—A direct oil-fired portable cover type furnace for annealing tinplate strip.



Courtesy of The Dowson & Mason Gas Plant Co., Ltd.

Fig. 16.—Continuous bright annealing furnace.

trays are traversed through the 9 ft. heating length by motor-driven pusher equipment fitted with reduction and variable-speed gears. A switch, incorporated in the pusher equipment, synchronised with the forward stroke of the pusher ram, operates the rising and falling door at the charge end of the furnace.

Heat treatment of the aluminium alloys, whether annealing or solution treating and age-hardening, involves temperatures around 500° C. or below. For such temperatures, particularly those used for artificial ageing (150°–200° C.), a salt bath or an air circulation furnace is necessary to ensure an even temperature throughout the charge. The examples of the latter type, shown in Fig. 18, are gas-fired and have a temperature range of 50°–550° C. with ± 1°C. variation throughout the 3 ft. 6 in. × 2 ft. 6 in. × 3 ft. working space. Provision is made for top loading and the 3 ft. × 2 ft. × 2 ft. basket holds some 6 cwt. of miscellaneous light alloy forgings. No products of combustion enter the working space, and the maximum gas consumption is 600 cu. ft./hr. with an average of 400 cu. ft./hr. This type of furnace is also made with electrical heating and is rated at 45 kW.

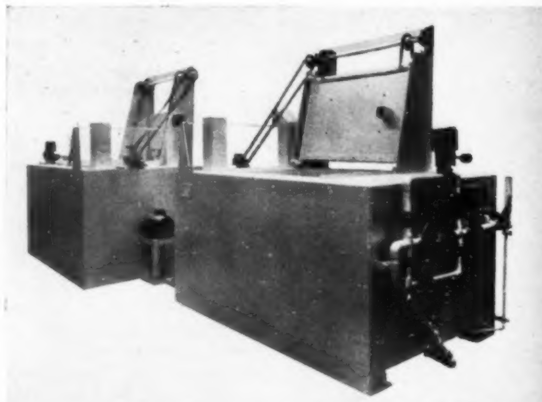
Courtesy of Thermic Equipment & Engineering Co., Ltd.

Fig. 17.—A continuous stainless steel sheet annealing furnace.

Annealing Malleable Iron

The first large Birlec installation for gaseous annealing of blackheart malleable iron has now been in production for some twelve months at Gloucester Foundry, Ltd. It consists of two electrically-heated furnaces of the well-known elevator type, operating in conjunction, one furnace being used for the low-temperature part of the annealing cycle, the other for the high-temperature soak, the loaded bogies being transferred from one furnace to the other at the required points in the cycle.

The two furnaces are of generally similar construction, having a charge space of 14 ft. × 5 ft. × 3 ft. 9 in. The high-temperature furnace is rated at 400 kW, while the low-temperature furnace is of 250 kW. The latter has various special features, such as cooling tubes, circulating fans and programme temperature control, for the purpose of accurate control of the slow-cooling part of the annealing cycle. The net charge accommodated varies between 9 and 12 tons, and the annealing cycle is 48 hours total—half in each furnace. The total output ranges between 60 and 80 tons/week at a power consumption of less than 390 kWH/ton.



Courtesy of J.L.S. Engineering Co., Ltd.

Fig. 18.—Top loading gas-fired air circulation furnaces for use in the temperature range 50°–550° C.

In the application of the gaseous process to the annealing of whiteheart malleable iron, Birlec report continuing progress, recent developments having been concerned more with the detailed construction of the furnace than with the basic process. With the accumulated experience of over 40 furnaces in the field, some of which have now been in operation for five years and longer, the desirability of certain changes in design have become apparent, particularly for the purpose of facilitating maintenance.

The Series III furnace, the first example of which is now in course of installation, is broadly similar to the earlier Series II furnaces but incorporates a number of important small modifications, particularly the provision of readily replaceable elements and element support pins, located on the side walls of the chamber only. This will enable element renewals to be made without the need for complete rebuilding. This change in element distribution has also enabled a slightly larger charge space to be provided. Twin coolers are also fitted to give improved temperature uniformity during cooling. This feature has been found to be of importance where the

highest physical properties in the annealed castings are required, and also where a foundry wishes to use the furnace alternatively for the annealing of blackheart malleable.

Carburising

Gas carburising is gradually being extended and many furnaces for carrying out this process have been installed recently. Of special interest are the furnaces shown in Fig. 19, which comprise part of Holland's largest gas carburising installation. Two of these are Wild-Barfield furnaces for carburising and hardening high-speed gears and pinions. These furnaces cope with the varying demands and types of products, are similar in construction and have a maximum operating temperature of 1,000° C. The larger furnace is rated at 240 kW, having a retort 40 in. in diameter and 80 in. deep, while the smaller unit is rated at 55 kW with a retort 16 in. in diameter and 30 in. deep. The smaller furnace is directly behind the larger one in the illustration; to the right is a forced air circulation furnace with the fan built into the lift-and-swing-aside door. In the right foreground is a salt bath for martempering.

Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 19.—Part of Holland's largest gas carburising installation are these two furnaces for the carburising and hardening of high-speed gears and pinions.

Evidence of the rising popularity of gas carburising is provided by the fact that one firm has supplied nearly 200 equipments to many and varied industries. Their latest model incorporates a sheet metal retort with an improved combination fan housing and work support, which is aerodynamically designed with special discharge jets enabling the powerful fan to circulate the furnace atmosphere through the densest of loads. Chemically constant and accurately metered Homocarb fluid is converted in the furnace into a carburising gas of the correct quality and quantity, the fan circulation ensuring that each piece is exposed to the same amount of gas. This completely integrated furnace equipment not only heats every part of the load uniformly, in an atmosphere of the specified carbon potential, but at the end of the soak, it cools it uniformly, protected by the Homocarb atmosphere, until it can be transferred to a cooling unit or to a quench tank. Fig. 20 shows a recent installation at the Derby works of Messrs. Rolls Royce, Ltd.

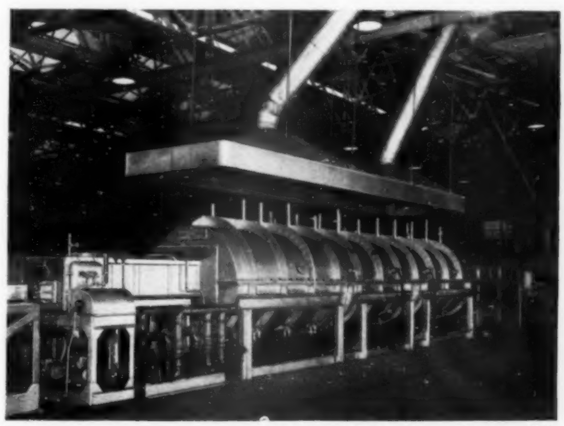
A continuous plant, installed at the works of The Standard Motor Co. Ltd., for gas carburising automotive

Courtesy of Integra, Leeds & Northrup, Ltd.

Fig. 20.—A recent gas carburising installation at the Derby works of Rolls Royce, Ltd.

components is shown in Fig. 21. The furnace is hermetically sealed to retain the carburising gas and to prevent infiltration of air. The furnace gas may consist of burnt town's gas from which all oxidising and decarburising agents have been removed. When the load has reached the required temperature, a carburising fluid is delivered through an atomiser into the carrier gas stream. The Incandescent Heat Co., Ltd. have developed the "Lithanol" gas carburising system, which uses a carburising fluid containing lithium compounds having a great affinity for oxygen. This system makes it possible to control the furnace atmosphere within the work chamber, since lithium will dissociate any traces of water vapour, releasing hydrogen and inhibiting the normal decarburising effect of any slight traces of CO_2 that may be present. This system is applied to the three main types of gas carburising installation, namely, lift-off, pit and continuous furnaces.

Beans Industries, Ltd., of Tipton, have recently entirely reorganised their heat treatment section to accommodate new equipment, and to leave as much room as possible for process work all electrical gear is mounted on overhead platforms. All-electric standard furnaces have been installed comprising four horizontal



Courtesy of The Incandescent Heat Co., Ltd.

Fig. 21.—A continuous plant installed for gas carburising automotive parts.

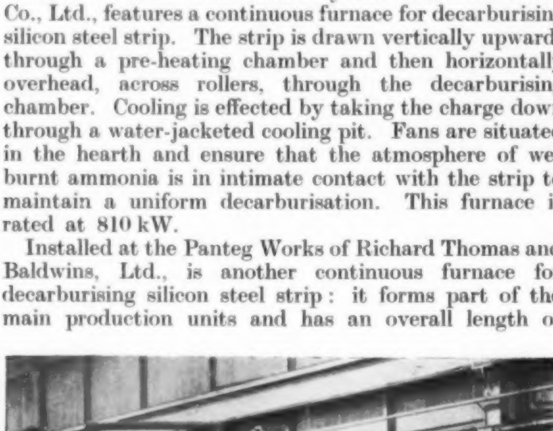
Courtesy of Birlec, Ltd.

Fig. 22.—An all-electric installation for general heat treatment.

batch units, each rated at 110 kW, with heating chamber dimensions of 7 ft. × 3 ft. 9 in. × 1 ft. 9 in. high, for pack carburising. Other units included in the installation are five batch reheating furnaces, each with a charge space of 5 ft. × 3 ft. × 1 ft. 6 in. high, a vertical forced air circulation tempering furnace, and a salt bath for hardening high-speed steel tools. This installation is shown in Fig. 22.

A new furnace installation by the General Electric Co., Ltd., features a continuous furnace for decarburising silicon steel strip. The strip is drawn vertically upwards through a pre-heating chamber and then horizontally overhead, across rollers, through the decarburising chamber. Cooling is effected by taking the charge down through a water-jacketed cooling pit. Fans are situated in the hearth and ensure that the atmosphere of wet burnt ammonia is in intimate contact with the strip to maintain a uniform decarburisation. This furnace is rated at 810 kW.

Installed at the Panteg Works of Richard Thomas and Baldwins, Ltd., is another continuous furnace for decarburising silicon steel strip: it forms part of the main production units and has an overall length of 118 ft. The plant incorporates a water-jacketed entry chamber having a sealing box leading the strip into the furnace, and a 60 ft. heating unit in the first part of which the strip is brought up to the required temperature in a relatively dry reducing atmosphere. The second part—the decarburising zone—is maintained at a temperature of 900° C., and has a special moist atmosphere with closely controlled water vapour and hydrogen contents. At the end of the furnace is a cooling zone about 27 ft. long which has a relatively dry reducing atmosphere. This furnace is shown in Fig. 23.

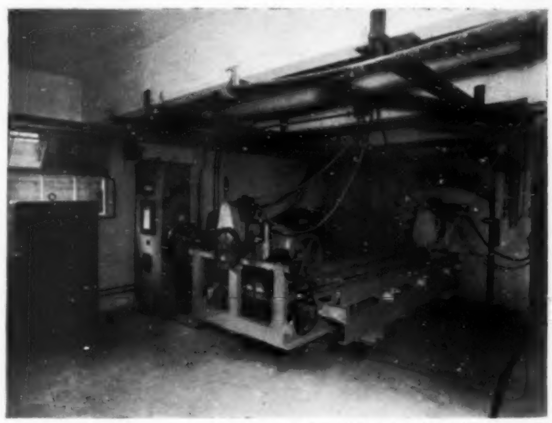


Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 23.—A continuous strip furnace for decarburising silicon steel strip installed at the Panteg works of Richard Thomas & Baldwins, Ltd.

Nitriding

An unusual hardness is imparted to the surface of nitriding steels when ammonia gas is fed into the furnace at appropriate temperatures. The gas breaks down into nitrogen and hydrogen, the nitrogen being particularly active in combining to a certain extent with alloying elements in the steel to form nitrides. After nitriding, resistance to wear and retention of hardness at elevated temperatures are among the chief qualities imparted to the steel. Special nitriding furnaces are designed to enable components to be nitrided.



Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 24.—A batch furnace for nitriding. The boxes have a usable capacity of 4 ft. 3 in. × 2 ft. × 1 ft. 4 in.

In addition to the straight nitriding process, another process has been developed, in which carburising and nitriding are combined, which is referred to as carbonitriding. This latter process, sometimes called gas cyaniding or dry cyaniding, is a gaseous case hardening process where the atmosphere supplied to the furnace is of a composition that allows both carbon and nitrogen to be absorbed by the steel in a ratio that can be precisely controlled. The atmosphere used consists of the normal gas-carburising atmosphere with the addition of cylinder ammonia as the source of nitrogen. The ratio of carbon to nitrogen entering the case is controlled by the ratio of the carburising gas to ammonia in the mixture admitted to the furnace, the type of steel being treated and the operating temperature involved. As with straight carburising, the concentration of the hardening elements, whether nitrogen or carbon and nitrogen, is highest at the surface of the steel and decreases progressively towards the core, hardening of the case being effected by either a separate preheat and quench or, preferably, by a direct quench.

An equipment for nitriding is shown in Fig. 24, which has a capacity to take nitriding boxes with usable dimensions of 4 ft. 3 in. × 2 ft. × 1 ft. 4 in. deep. The furnace, rated at 48 kW, has a maximum working temperature of 750° C. The boxes are fitted with atmosphere circulating fans, the atmosphere being fed through the door seen in the illustration. A loading machine is provided which traverses between two such furnaces so that loading of the boxes is arranged alternately.

The new Efco-Lindberg carbo-nitriding furnace (Fig. 25) is an interesting development in design. It is a gas-fired, vertical radiant tube furnace with a built-in quench tank. Before passing to the heating chamber, the work enters a vestibule immediately above the quench tank where it is preheated to avoid drastic temperature change, the work being completely purged while it is being preheated. The heating chamber is fitted with roller rails, and the loading table and a 2-deck elevator are equipped with conveyor rollers to facilitate loading. An atmosphere fan, vertically mounted below the furnace, provides an even and constant circulation of the furnace atmosphere through the work load, assuring uniformity of case depth and temperature. The heating chambers are 24 in. wide × 36 in. long × 15 in. high. With high ammonia concentrations in the furnace atmosphere, case hardening at temperatures as low as 650° C. is possible, and in this field the process is a modified nitriding process where plain carbon in addition to alloys steels may be given a hard, shallow, wear-resistant surface. The more general application, however, is in the case hardening range of 800°–870° C., using propane additions of 2 to 6% and ammonia additions of 6 to 20%, depending upon the type of case and operating temperature required.

Recently installed at the works of Messrs. D. Napier and Sons, Ltd., is a Homo nitriding furnace in which large loads of components can be treated to provide cases uniform both as to hardness and depth by means of the forced circulation method used. In this furnace the heat treater has control of the three important factors—nitriding temperature, flow and distribution of ammonia gas, and duration of treatment. Any of the three can be varied and the other two held constant, thus controlling succeeding batches in such a way as to progress systematically towards the case required. Then by holding constant on batch after batch, the required case can be duplicated easily and surely.

Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 25.—An Efco-Lindberg carbo-nitriding furnace.

Courtesy of Birlec, Ltd.

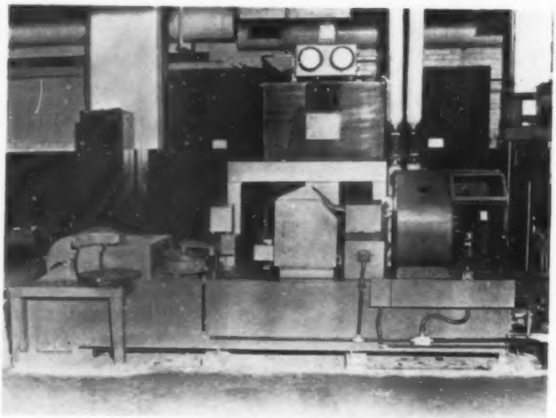
Fig. 26.—A Birlec-Dow furnace for carbo-nitriding.

It is claimed that the first specially designed carbo-nitriding furnace was by the Dow Furnace Co. of the United States, and a large number of installations are now in successful operation. Recently Birlec, Ltd., concluded an agreement with the Dow firm to manufacture to their design in this country, and the first Birlec-built furnace is now available for test and demonstration purposes. This furnace, shown in Fig. 26, is of the horizontal batch type, heated by vertical gas-fired radiant tube elements in conjunction with a powerful circulating fan placed in the roof of the chamber. A special feature is the provision of high thermal storage in the heating chamber, which aids rapid temperature recovery after insertion of a new charge, so ensuring minimum treatment times and high output. Another feature is the provision of generators of endothermic type, for the production of the carrier gas for the furnace atmosphere, integral with the heater tubes, whereby the necessity for a separate generator and its required floor space are eliminated. The front of the furnace is sealed by an enclosed vestibule, which is situated immediately above the integral oil quench tank; simple mechanical devices are incorporated for withdrawal of the charge into the vestibule and lowering into the tank, where powerful directional circulation ensures efficient quenching and a clean finish.

Induction Hardening

As stated by Howard,[2] induction heating is not, strictly, a furnace application; in many cases there is no

[2] J. C. Howard, *J. Iron and Steel Inst.*, 1952, **173**, 285-291.



Courtesy of Electric Furnace Co., Ltd.

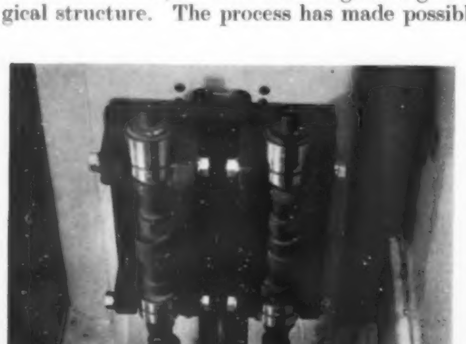
Fig. 27.—Three-station equipment for H.F. induction hardening of push-rods, rocker arms and tapped screws.

furnace in the accepted sense. Apart from the work-piece, nothing is hot, and cold water is much more evident than heat. Induction heating, however, carries out a metallurgical function that would otherwise be done in a conventional furnace, so that reference to it is logical.

Induction hardening can be applied with the greatest advantage to mass production. A suitable inductor placed near the work-piece induces electric currents in its skin, and the power concentration is so proportioned that the surface is heated to hardening temperature before the core is hot. Thus, on quenching, only the case is hardened, the core retaining its original metallurgical structure. The process has made possible a much wider use of plain-carbon steels, because it is possible, by suitable selection and prior treatment, to have—with the cheaper plain-carbon steels—case and core properties that can otherwise be obtained only with alloy steels. By this means, parts in the soft state can be finish-machined and subsequently hardened without distortion or oxidation.

An interesting 3-station induction hardening unit, fed by two 5 kW 450 kc valve generators is shown in Fig. 27. The centre station for hardening the ends of push rods is connected to both valve generators when in use, both ends being hardened simultaneously. When this station is not in use, the other two stations for rocker arms and tappet screws are fed independently by the two valve generators. In each case inductors of channel type are used, the parts being passed through the inductor at predetermined speed. On emerging from the inductor, the part is automatically discharged into a quench bath below. The quench bath extends under the three stations and is provided with a conveyor for the removal of the hardened parts. Ingenious mechanisms are provided for carrying the parts through the inductors and subsequently quenching them. This equipment is installed at the Luton Works of Vauxhall Motors, Ltd. and has an output of 1,500 push rods or 1,200 rocker arms and 2,400 tappet screws per hour. These outputs are determined by the operator, but hopper feed to obtain increased output is being considered.

The station shown in Fig. 28 is designed for hardening the driving gear on two camshafts simultaneously using a 2-hole single turn inductor with incorporated spray quench. The camshafts are mounted in a spring-loaded recess in a carriage moving on a vertical face plate. The carriage, which is counterbalanced, is moved down

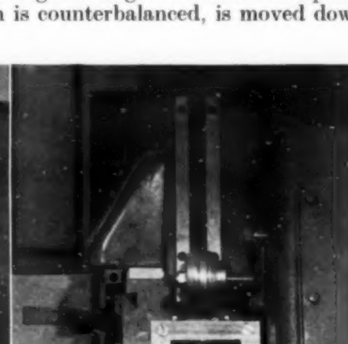


Courtesy of Electric Furnace Co., Ltd.

Fig. 28.—Equipment for H.F. induction hardening of the driving gear on camshafts, using a 2-hole single turn inductor with incorporated spray quench.

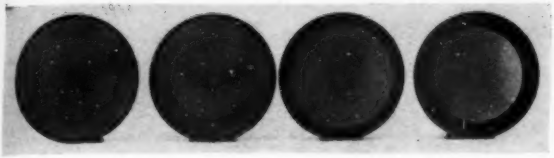
Courtesy of The General Electric Co., Ltd.

Fig. 29.—A high-frequency bar stock hardening machine showing two bars on the V-slide.



Courtesy of The General Electric Co., Ltd.

Fig. 30.—The V-slide and rollers with the cover removed. The flexible pipe is connected at the top to the quench box.



Courtesy of The General Electric Co., Ltd.

Fig. 31.—Some of the varying thicknesses of hardened case obtained by varying the speed of the bar through the heating coil.

to a stop which accurately positions the gears in the inductor. At the same time current is switched on to the inductor for a predetermined time followed, after a set delay, by the turning on of the spray switch. At the end of the hardening cycle a pilot lamp indicates that the carriage may be raised and the camshafts removed and replaced. The station is fed from a 100 kW 10,000 cycle generator, the size of which is determined by two other stations which harden the cam and bearing surfaces, respectively. The three stations are operated in sequence, the generator being switched from one to the other as required. The total output is 80 camshafts/hr.

A machine for induction hardening steel bars is shown in Fig. 29. It is intended for use with hardenable steels rather than with carburised bars. Operation is continuous, the bars being placed one at a time against the top of the inclined V-slide, Fig. 30, and allowed to pass down the slide and through the heating coil. The speed with which the bars pass through the heating coil is governed by two driven V-rollers, one situated above and one below the heating coil. The two rollers are geared together and driven by the same prime mover. Immediately below the heating coil is an annular quench box through which the heated bar passes when it leaves the heating coil. As each treated bar is finished it slides down a chute and is collected in a basket at the bottom. The thickness of the hardened case depends upon the speed with which the bars travel through the heating coil, as illustrated in Fig. 31. This machine, which is rated at 25 kW output, when treating 1 in. dia. bars at 30 in./min. gives a hardened case 0·025 in. thick.

In suitable cases, application of the induction hardening method to finished gears can show marked advantages and cost savings over alternative heat-treatment methods and a prototype unit for this purpose, which was on view at the recent International Machine Tool Exhibition, is shown in Fig. 32. This new machine operates in conjunction with a 25 kW valve oscillator type generator and can handle a large variety of sizes and types of gears. It is designed for tooth-by-tooth operation and is equipped with suitable traversing and indexing mechanisms. By use of different inductors and associated quench units, which are readily interchangeable, various types of hardened pattern can be produced, e.g. through hardening of the tooth, hardening of the flanks only, or hardening of the flanks and roots. The last-named is the most desirable pattern for highly stressed gears, and duplicates most nearly the structure obtained by conventional case-hardening methods.

The induction method of rapid selective heating enables localised heating of components without interference with adjacent parts. Fig. 33, for example, shows a two-station induction heating work table for hardening axle shafts. At the right hand work-station it will be seen that the forgings have been lowered into the coils

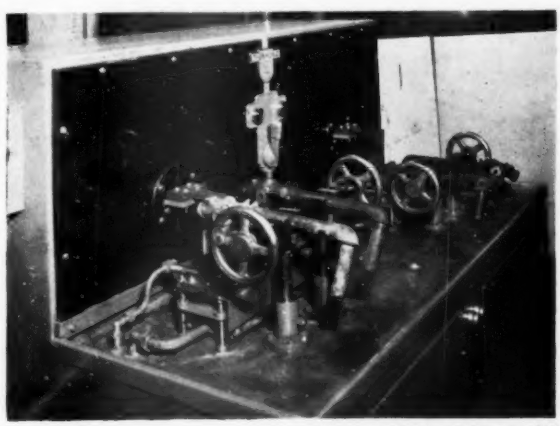
Courtesy of Birlec, Ltd.

Fig. 32.—Prototype high-frequency gear tooth hardening machine.

for heating, while at the left hand station the forgings have been reversed in the jig ready for heating the opposite ends. Quenching is controlled by a simple process timer which operates when the components have reached the required temperature, thus ensuring speedy quenching and maximum hardness.

Hardening and Tempering

New plant installed for the treatment of caterpillar track plates and similar work includes double-ended electrically-heated batch-type hardening and tempering furnaces, complete with high-speed quenching gear, such as those shown in Fig. 34. The combined furnaces shown are designed to handle a total output of 75 tons/week. Both furnaces are adequately zoned and are



Courtesy of Metalectric Furnaces, Ltd.

Fig. 33.—A two-station induction heating work-table for hardening axle shafts.

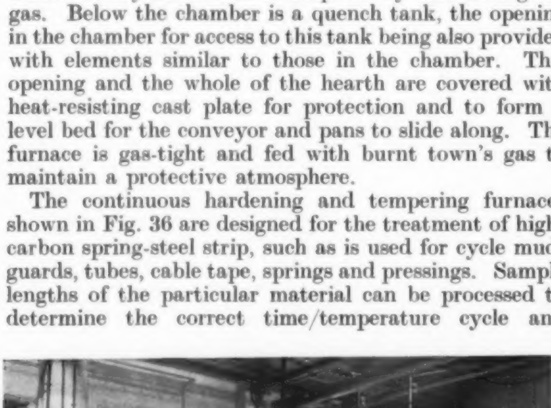
Courtesy of McDonald Furnaces, Ltd.

Fig. 34.—Electrically-heated batch type hardening and tempering furnaces for the treatment of caterpillar track plates.

similar in design, but the tempering furnace is provided with circulating fans to ensure rapid and even heating at the lower temperature. To ensure consistent quenching, an oil cooler is connected to the tank and incorporates a temperature controller.

A recent installation at the Redditch works of Messrs. Herbert Terry and Sons, Ltd., is a pan conveyor furnace, shown in Fig. 35, which is used for hardening and tempering large quantities of small components, such as springs, clips, brackets, cranks, levers, spindles, etc. It consists of a heating chamber 64 in. long × 23 in wide × 6 in. high, heated by tubular elements in the roof and hearth. At each end of the chamber, ducts are mounted to give a satisfactory balance of atmosphere by contracting the gas. Below the chamber is a quench tank, the opening in the chamber for access to this tank being also provided with elements similar to those in the chamber. This opening and the whole of the hearth are covered with heat-resisting cast plate for protection and to form a level bed for the conveyor and pans to slide along. The furnace is gas-tight and fed with burnt town's gas to maintain a protective atmosphere.

The continuous hardening and tempering furnaces shown in Fig. 36 are designed for the treatment of high-carbon spring-steel strip, such as is used for cycle mudguards, tubes, cable tape, springs and pressings. Sample lengths of the particular material can be processed to determine the correct time/temperature cycle and ensure uniformity of treatment as the material passes continuously through the furnaces and flow production proceeds. The strip is drawn through the furnace within ducts fabricated from nickel-chromium heat-resisting alloy steel, which not only facilitates the maintenance of a uniform temperature within the duct itself but also enables a protective atmosphere to be conveniently provided. The atmosphere is supplied either by burning town's gas in an exothermic plant, or by introducing raw gas into the duct, and since the cross-section of the latter is the smallest compatible with the charge being processed, consumption is reduced to a minimum. Tunnel effect losses, both of heat and atmosphere, are further reduced by fitting inlet vestibules to both the hardening and tempering furnaces. The installation illustrated has a total rating of 72 kW—48 kW for hardening and 24 kW for tempering. Each unit is designed for an output of up to 2 cwt./hr. of steel strip ranging from 0·010 to 0·064 in. thick. Such strip is usually processed at speeds of about 7–2 ft./min.



Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 35.—A pan conveyor furnace for hardening and tempering large quantities of small components.

Recently installed at the works of Messrs. John Fellows, Ltd., is an electrically-heated mesh-belt furnace, Fig. 37, incorporating a novel feature which enables the furnace to be used efficiently and economically for both hardening and normalising. The furnace, which has an output of 5 cwt./hr., is provided with an automatically controlled bolt feeder which ensures a constant and consistent rate of flow on the belt, and also a compact exothermic generator which supplies an artificial protective atmosphere. The mesh belt, which

Courtesy of G.W.B. Electric Furnaces, Ltd.

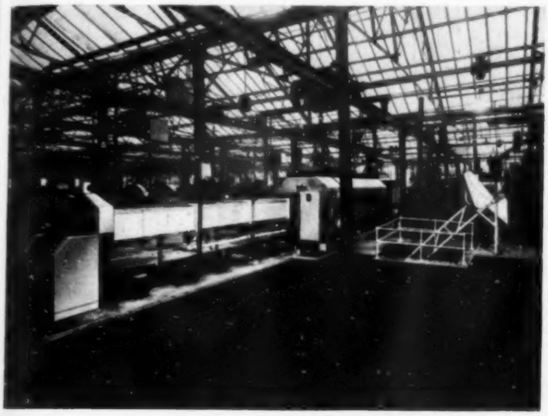
Fig. 36.—Continuous pull-through furnaces for hardening and tempering strip steel. Each furnace chamber is 15 ft. long and 6 in. wide, the cooling duct at the end of the tempering furnace being 25 ft. long.

is an accepted conventional method of conveying, is generally used only where the furnace is designed for one specific purpose. By introducing an ingenious device,* at the discharge end of the heating chamber, which is controlled by a handle outside the furnace, bolts can be discharged direct into the quench tank, the latter being equipped with a suitable conveyor for bringing the bolts to floor level.

There are two main types of armour plate, namely, homogeneous and face hardened. The furnaces for heat treating both kinds of this material are similar when

* Patent pending.

designed on Incandescent-Drever continuous armour plate lines, the only difference being the quenching equipment and the quenching medium used. Homogeneous plate is quenched in water, whereas face-hardened plate is always quenched in oil. For homogeneous plate, a pressure quench is used. The water is supplied by an automatically controlled pump which has a capacity of 2,000 gallons/min. Pressure is applied to the plate when it is in its most plastic state, thereby flattening it, while water is applied in large volume to both faces of the plate. Pressure quenching is not used for face-hardened plate because of the difference in chemical and physical composition between the high and low carbon sides of the plate. From the hardening



Courtesy of McDonald Furnaces, Ltd.

Fig. 37.—An electrically-heated continuous mesh-belt furnace incorporating a novel feature, enabling the furnace to be used economically for hardening and normalising.

furnace, the heated plate is discharged on to an elevator which submerges it in an oil quench tank. A typical Incandescent-Drever heat treatment line for armour plate, showing the hardening furnace, quench equipment and tempering furnace, is illustrated in Fig. 38.

Forming part of a gas-carburising installation at the works of the Rover Co., Ltd., is the rotary-hearth hardening furnace shown in Fig. 39. The advantage of this type of furnace, apart from the obvious saving of floor space, is that it requires only one operator for loading and unloading. In this installation, passage through the furnace takes about 45 minutes, in which period the work is brought up to a temperature of 800°–810° C.

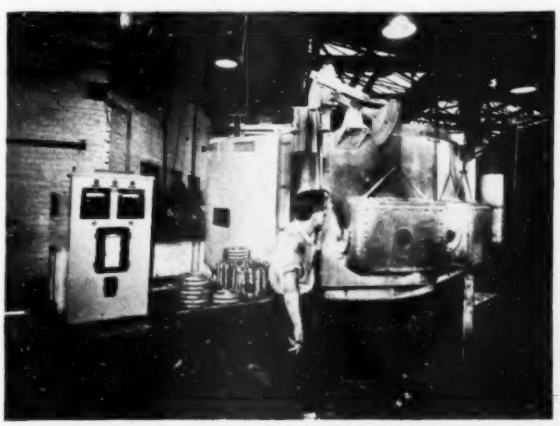
The newest addition to the Integra, Leed and Northrup range of tempering furnaces is the Homo high-temperature tempering furnace. This furnace can be operated up to a maximum temperature of 900° C. and permits many operations to be performed which could not be handled with the lower-temperature type of tempering furnace. Such operations as cycle annealing, spheroidising, normalising, stress relief, and other allied treatments, can be carried out on almost any ferrous or non-ferrous parts. Not only does this furnace give quality production in the range 650°–900° C., but, at a given load and temperature, it performs as efficiently as the 425° C. and 760° C. Homo tempering furnaces. Thus, on straight tempering operations, it can be used interchangeably with other Homo furnaces having lower

Courtesy of The Incandescent Heat Co., Ltd.

Fig. 38.—A typical Incandescent-Drever heat-treatment line for armour plate showing the hardening furnace, quench equipment and tempering furnace.

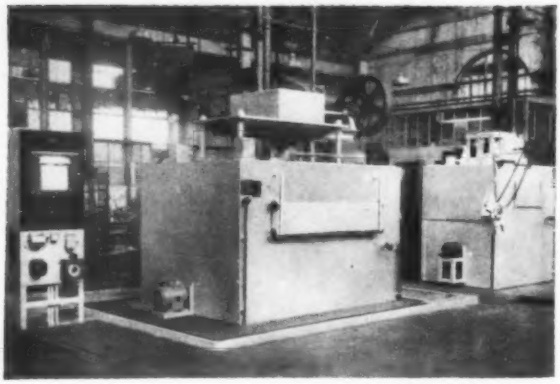
temperature ranges. Based on the forced-convection Homo principle in combination with the Micromax electric control system, this furnace equipment brings every piece in the load to uniform temperature, and holds every piece at that temperature for a uniform time, thus regulating the two factors which determine the success or failure of production-tempering and allied operations.

In Fig. 40 can be seen two units which are known in the saw trade as goffs. The object of a goff is to temper a quantity of saws, circular or straight, so that they are of the correct temper and absolutely flat. The goffs shown are gas-fired air circulation furnaces in which the products of combustion do not enter the working spaces. A hand-operated press, all complete, is lowered into position through the top of the furnace and fixed. The saws are stacked between the press dies whilst the furnace is at temperature and the press closed. The saws temper and flatten under pressure, and after a definite tempering period they are removed from the press and stacked ready for a minimum of final tensioning and setting by the saw-smith. The unit situated centrally in the illustration deals with saws of 18–48 in. in diameter and $\frac{1}{8}$–$\frac{5}{16}$ in. in thickness, whilst the corresponding



Courtesy of G.W.B. Electric Furnaces, Ltd.

Fig. 39.—A rotary hearth hardening furnace which effects saving in floor space.



Courtesy of J.L.S. Engineering Co., Ltd.

Fig. 40.—Two gas-fired air circulation "goffs" for tempering saws at the works of Firth-Brown Tools, Ltd.

figures for that on the right hand side are 6–20 in. and 16 s.w.g.—¼ in.

Salt Baths

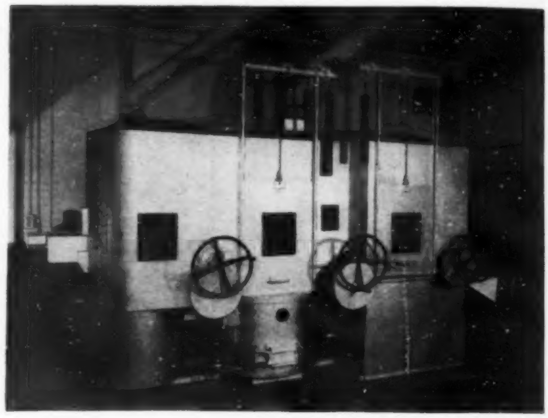
In our last review of developments in heat-treatment furnaces, details were given of recent developments in molten salt bath practice, involving reduced costs of operation and improved working conditions by collection and disposal of fume. Progress has continued along these lines and in the development of new outlets for existing salt bath processes, including deep carburising of components like camshafts in accelerated carburising salt baths. An increased number of applications are being found for the processes of austempering and martempering. Fig. 41 shows a large salt bath furnace produced for austenitising metal die-casting dies, prior

Courtesy of Imperial Chemical Industries, Ltd.

Fig. 41.—A large "Cassel" "S" type salt bath furnace for austenitising diecasting dies prior to martempering by quenching in a second salt bath at a lower temperature.

to martempering by quenching into a second molten salt bath at a lower temperature. Experimental work has resulted in the successful hardening of very large roller bearing races in 1% carbon-chromium steel (En. 31), for jet engines by martempering in a salt bath at 250° C. Further work has been done in applying martempering, using a fully automatic salt bath, to smaller races in En. 31. A relatively new field for martempering is the use of large salt baths for austenitising and quenching of large forging die blocks. These are die-sunk in the annealed state and subsequently hardened free from scale and with minimum of distortion by the martempering process, which is followed by a tempering treatment in salt.

Fig. 42 shows a totally-enclosed hand-operated salt bath installed for hardening with a brine quench. Parts



Courtesy of Imperial Chemical Industries, Ltd.

Fig. 42.—A totally enclosed hand-operated "DE" type "Cassel" salt bath installed for hardening, with a brine quench.

are fed into a hopper at the left of the illustration whence they fall, by tripping of the hopper, into a basket suspended in a preheater heated by waste gases from the salt bath. Manual operation transfers the preheated parts to a basket immersed in a neutral salt bath, from which they are tipped at the appropriate time into a brine quench. The parts are subsequently discharged into a waiting container.

Another type of totally-enclosed salt bath now built is that shown in Fig. 43. In this type, small work to be cyanide hardened is loaded outside the canopy into baskets which are then carried by a crane through swinging doors in the canopy and placed in a preheater. After preheating, basket and parts are transferred to a cyanide melt in the furnace proper, given the appropriate soaking time, then transferred by crane to tipping cradles which enable the parts to be tipped from the baskets into water or into oil. The parts are removed in the quenching baskets, by crane through swing doors at the opposite end to entry. Since preheater, salt bath, and water and oil quenching tanks are under a common canopy, it is a simple matter to collect and dispose of the fume coming off work being transferred from salt bath to quench.

There has been progress in the application of electricity to salt bath practice ; a faster rate of heating is possible

Continued on page 274

Latest designs now available *in* GREAT BRITAIN!

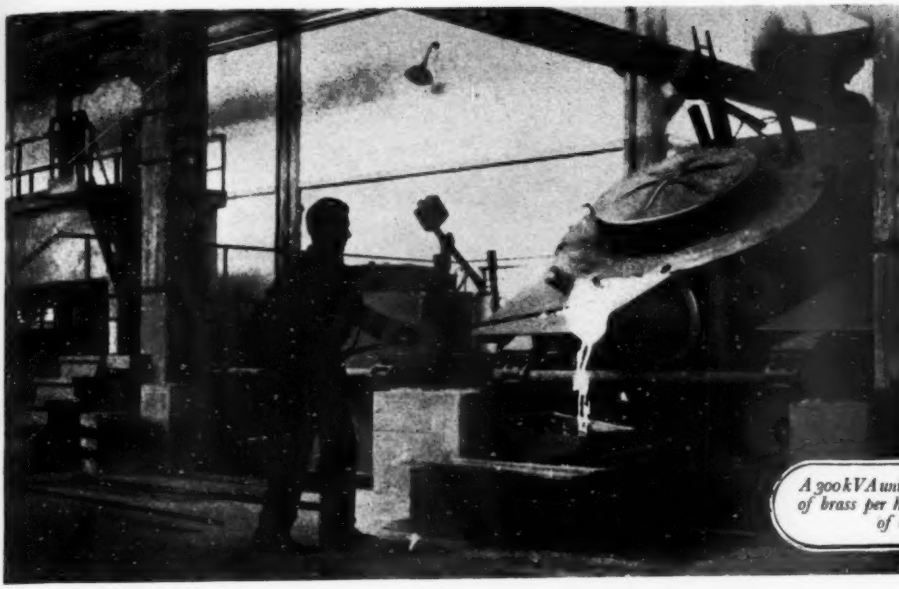
For normal and special cast irons standard sizes of G.W.B.-A. Tagliaferri furnaces are available for molten metal outputs of 140 to 2,000 lbs. per hour. Particularly suitable for thin wall castings, the furnaces can operate from cupola melted molten metal or melt from cold. To meet the modern tendency towards the use of high duty irons these furnaces are ideal for alloying, and strict control of the analysis and temperature of the product can be maintained. A standard range of induction furnaces is also available for light metal alloys having outputs of from 100 to 1,750 lbs. per hour and for copper and its alloys from 50 to 4,000 lbs. per hour. We will be pleased to quote for furnaces for special requirements.

MAINS FREQUENCY CORE TYPE

Two model G.400 induction furnaces supplying molten cast-iron to a foundry manufacturing motor car parts.

G.W.B. ELECTRIC FURNACES LTD.

Proprietors:- Gibbons Bros. Ltd., & Wild-Barfield Electric Furnaces Ltd.
Dibdale Works, Dudley, Worcs. — Telephone: Dudley 4284



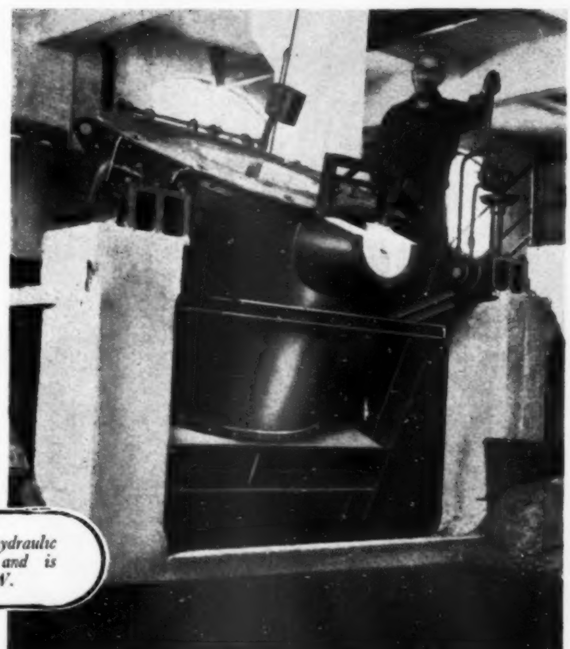
A 300 kVA unit, to melt 2,200 lbs. of brass per hour, or 1,760 lbs. of bronze.

GWB-TAGLIAFERRI

INDUCTION MELTING FURNACES

Among their many advantages are:-

- Initial starting without using hot metal.
- Positive metal circulation without turbulence giving maximum refractory life.
- Special channel design on furnaces for light metals facilitates cleaning without the need for completely emptying the furnace.
- The refractory lined casing is easily exchanged with the relined spare without removing electrical connections or inductors.
- Clear indication is given when end of lining life is approaching.
- Refractory lining of melting duct can be repaired without dismantling the furnace.



This unit has hydraulic tilting mechanism and is rated at 210 kW.

We design to suit your particular operation...

This Multi-Chambered Forge Furnace was installed by us recently in the New Forge of Stavanger Electro-Staalverk A/S. It was designed for the controlled heating of a wide range of highly alloyed steel ingots of various sizes which have to be gradually raised from cold through successive critical temperatures to the final forging heat.

The plant consists of four primary and two secondary preheating chambers, two tertiary heating chambers and two final chambers for the reheating of semi-forged products. The furnace is oil fired and has full instrumentation. The doors are oil-hydraulically operated from a central control room.

WINCOTT FURNACES

G.P. WINCOTT LIMITED SHEFFIELD, ENGLAND

Telegrams: WINCOTT, SHEFFIELD. Telephone: 20211/2

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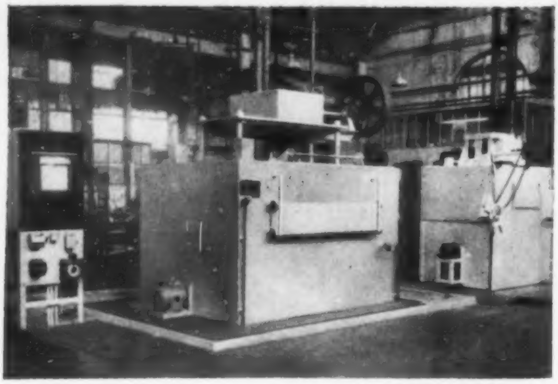

Courtesy of J.L.S. Engineering Co., Ltd.

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Courtesy of Imperial Chemical Industries, Ltd.

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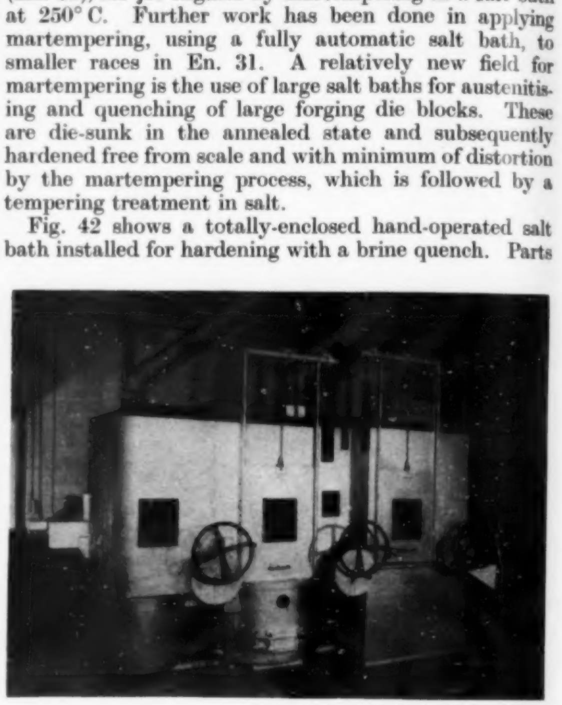

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Continued on page 274

NEWS AND ANNOUNCEMENTS

£1,000 Fellowship in Metallurgy

THE Victorian Agent-General in London, The Hon. Sir John Lienhop, announces details of a Fellowship in Metallurgy which is to be made available during 1954 to a British subject with at least ten years' residence in the United Kingdom. The " British Memorial Fund " has been established by citizens of the State of Victoria, Australia, as a " gesture of loyalty, gratitude and affection " to the British people in recognition of their "role in saving civilisation in the Second World War." It takes the form of offering, each year, a number of Fellowships, tenable in Victoria, to graduates and young persons in the United Kingdom in the hope that they will return to their own country with a desire to strengthen the ties between it and Australia.

The Fellowship is for £1,000 (Australian). This is to cover travelling expenses to and from Melbourne and ten months' living expenses in the State. The tenure would normally be for the academic year commencing March, 1954, and candidates should be prepared to travel to Victoria during January, 1954. Accommodation will be arranged for selected candidates. Wives and children are welcome but no extra expenses can be paid to cover them. Applicants for the Fellowship must be under the age of 35 on the 1st January, 1954. The Fellowship is available to any graduate, diplomate or specialist in primary metallurgical processes in the production of concentrates and metals from their ores, and the Fellow will work in close liaison with the Professor of Metallurgy at Melbourne University who will make facilities available for research of a type in which the Fellow shows particular interest.

Full particulars may be obtained from The Hon. Sir John Lienhop at Victoria House, Melbourne Place, Strand, London, W.C.2, the closing date for the receipt of applications being the 10th June, 1953.

Simultaneously with the Metallurgy Fellowship, similar Fellowships are being offered by the Fund for Pre-School Education and Child Development ; Arbitration (Industrial) ; and British Commonwealth Studies. The same conditions apply in each case. The Agent-General is Chairman of the London Selection Committee. Other members are Lady Albermarle, Lord Huntingfield, Lord Baillieu, Sir Vincent Tewson, Sir Angus Gillan, and Dr. J. F. Foster.

Metal Finishing Conference

THE International Conference on Electrodeposition and Metal Finishing, sponsored by the International Council for Electrodeposition, of which body the Institute of Metal Finishing (Great Britain) and the American Electroplaters' Society (U.S.A.) are prominent members will take place in, or near, London in April 1954, Plans are being made actively to this end by appropriate Committees appointed by the International Council. The Technical Sub-Committee of the Conference Committee now invites authors to submit manuscripts which will be considered by the Publications Committee of the Institute of Metal Finishing for presentation at the Conference. Papers should preferably deal with work of an original nature in the field of electrodeposition and metal finishing generally. Manuscripts should be forwarded to the Honorary Secretary of the Institute of Metal Finishing, Dr. S. Wernick, at 32, Great Ormond Street, London, W.C.1.

The Use of Electrons in the Examination of Metals

Summer School at Cambridge

A SUMMER school in the use of electrons in the examination of metals will be held in the Cavendish and Goldsmiths' Laboratory at Cambridge during the period 20th–31st July, 1953. Summer schools have been held previously in Cambridge on electron microscopy, but the subject has become so diverse that in co-operation with the Institute of Metals a more specialised course has now been arranged. This will consist of lectures, demonstrations and practical classes in the principles of the electron microscope and electron diffraction camera and their practical applications to the study of metals. Practice will be provided in the standard methods of replica and specimen preparation, and the new technique of reflection electron microscopy for the direct examination of metals will be discussed and demonstrated. A detailed syllabus and form of application for admission may be obtained from G. F. Hickson, M.A., Secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge, to whom the completed application form should be returned not later than 30th May.

Sir Arthur Smout

THE COUNCIL of the Institute of Metals has elected Sir Arthur Smout, J.P. (Past-President), a Fellow, in recognition of his long and distinguished services to the Institute. The number of Fellows is limited to twelve. Entering the Elliott Group of metal companies in 1905 as a student apprentice, Sir Arthur remained with the Group, and with what is now the Metals Division of Imperial Chemical Industries, into which Elliott's was merged in 1927, until his retirement earlier this year from the Main Board of Imperial Chemical Industries, Ltd. Apart from two short breaks in accordance with the constitution, Sir Arthur held office as Member of Council, Vice-President, President and Past-President of the Institute from 1924 to 1953.

B.I.S.R.A. Appointment

MR. C. H. KINGTON, M.B.E., Chief Engineer and Administration Officer at B.I.S.R.A.'s Sheffield laboratories, has in addition been appointed Group Manager. Three of B.I.S.R.A.'s separate divisions (those concerned with steelmaking, mechanical working and metallurgy) are carrying out independent work at these laboratories, which also accommodate the staff of the Cutlery Research Council. As the laboratories approach completion the work is increasing in scope, and in his new capacity Mr. Kington is particularly concerned with the relation of the group as a whole to the Sheffield industry, the University, civic authorities, etc., and for the co-ordination of efficient utilisation of all equipment and resources.

Rutherford Memorial Lecture

THE Council of the Royal Society has appointed as the Rutherford Lecturer for 1953 Sir James Chadwick, F.R.S., who will deliver the Lecture at McGill University, Montreal in the autumn. This is the second Rutherford Lecture to be delivered under the terms of the Rutherford Memorial Fund, the first having been delivered last year in New Zealand by Sir John Cockcroft, C.B.E., F.R.S.

Institute of Marine Engineers

AT the recent Annual General Meeting of the Institute of Marine Engineers it was announced that Viscount Weir had made a gift to the Institute of £10,000 to be used or applied in benefiting the work of the Institute in any useful direction. The Honorary Treasurer, Mr. Alfred Robertson, C.C., also announced that interesting developments were taking place concerning the proposed new premises in connection with the National War Memorial to Marine Engineers who gave their lives during the last war.

French Steelworkers Visit Wales

Two technical missions, whose members are shortly to visit the United States to study blast furnace practice and steelmaking, respectively, came over from France for a few days last month to see a number of major works in South Wales. It was felt that such visits would be of great value, particularly as the terminology and language are, on the whole, the same in both British and American steelworks. The companies visited were: Guest Keen Baldwins Iron & Steel Co., Ltd. (Cardiff), Richard Thomas & Baldwins, Ltd. (Ebbw Vale), and The Steel Company of Wales (Port Talbot).

Welding Congress in Hamburg

BY choosing Hamburg as the venue for its Great Welding Congress, the Deutscher Verband für Schweisstechnik EV. has given expression to the increasing use of welding in the construction of ships, marine engines and ports. The papers to be presented reflect this trend, but there will be many other subjects discussed, including ultrasonic testing of welds, the weldability of steel, the economies of lightweight steel construction, and the application of modern welding methods to railway track building. The Congress will be held from June 15th to June 19th, 1953, at the time of the International Horticultural Show in Hamburg.

The Utilization of Low Grade Ores

O.E.E.C. Mission Visits Britain

A MISSION from the Organisation for European Economic Co-operation visited this country recently to gather facts on research into the exploitation of low-grade ores. The party spent five days in visiting laboratories and mines and held informal consultations with British experts. The mission will also visit France, Germany, Italy and Sweden. It is hoped that, as a result of the mission, closer co-operation between organisations interested in mineral dressing will come about, and methods will be developed of mining and dressing low-grade ores which have, as yet, been uneconomic to mine.

The mission includes experts from Austria, Belgium, France, Germany, Greece, Italy, Norway, Sweden, Turkey and the United States of America. British representatives are Professor J. A. S. Ritson, and Dr. W. Davies, head of the Ore Dressing Laboratory of the United Steel Companies, Ltd. The secretary of the mission is Mr. J. Sandor of the Department of Scientific and Industrial Research.

Among the establishments visited by the party were the Mineral Dressing Laboratories at Harwell, the Research Laboratories of the General Electric Company, the Bessemer Laboratories of the Royal School of Mines and mines at Plymouth, St. Austell and Pendeen. At the end of the tour in the United Kingdom the mission met for informal discussions at the headquarters of the Department of Scientific and Industrial Research.

Personal News

THE English Electric Co., Ltd., announce that the RT. HON. THE VISCOUNT CALDECOTE, D.S.C., has been elected a Director of the company.

MR. W. B. G. COLLIS has been Assistant Sales Manager in the Traction Department of Metropolitan-Vickers Electrical Co., Ltd., and is in charge of Traction Sales in London.

MR. R. W. RUTHERFORD has been appointed Deputy Managing Director of The Power-Gas Corporation, Ltd., and Ashmore, Benson, Pease & Co., Ltd., of Stockton-on-Tees. He joined the first-mentioned company in 1917 and was appointed to the Board of Directors in 1948. He is also a Director of an associate company, Rose, Downs & Thompson, Ltd., of Hull.

MR. N. L. GOODCHILD has resigned his appointment as Raw Materials Officer of the British Iron and Steel Federation. Mr. Goodchild was previously General Manager of B.I.S.C. (Ore), Ltd., and from 1939 to 1946, Director for Pig Iron and an Assistant Controller of Iron and Steel in the Ministry of Supply. He was one of the Technical Advisers to accompany the European Mission to America in 1947, headed by Sir Oliver Franks, in connection with the Marshall Plan.

MR R. STEWARTSON, Head of the Metal Forming Section of the Research and Development Department of United Steel Cos., Ltd., has been elected to the Council of the Institution of Mechanical Engineers, representing the Associate Members.

MR. J. S. BIRD has been appointed Sales Liaison Executive to Kent Alloys, Ltd.

NEWMAN Industries, Ltd., announce that MR. R. J. SHAWYER has been appointed General Manager of Newman Industries (Australia) Pty., Ltd., the recently established subsidiary, and that MR. R. F. SHEARMAN has been appointed Technical Representative for the parent company in the United States.

MR. J. DUTHIE has been appointed a Director of The Darlington Forge, Ltd., and MR. R. C. BENSON a Special Director of the same company. Mr. Duthie first joined Darlington Forge in 1936 and later represented the company on the North-East coast until his appointment as Sales Manager in 1948. He was made a Special Director in 1950. Mr. Benson, after being in charge of the forging presses at English Steel Corporation's River Don Works for many years moved to Darlington Forge, as Forge Manager, in 1936.

THE Ministry of Supply announces that MR. R. F. RUCKER has been appointed Director of Non-Ferrous Metals in succession to MR. C. A. JAMES.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Storage System of Space Heating

An idea has been developed by The General Electric Co., Ltd., to enable electricity to be utilised for space heating purposes without affecting the demand for electricity at peak periods. For some years past it has been the practice on the Continent to use, for reasons of economy, a small fire to heat a mass of brickwork which is allowed to give out its stored heat to the surrounding air and thus provide background heating over a long period. By the use of concrete and a small, specially designed electric element mounted in a simple sheet steel case of attractive appearance, the G.E.C. has obtained the same effect. These electric thermal storage radiators are designed for use on a time-switch-controlled circuit so arranged that the radiators draw their power during the night, when power stations are not troubled by a peak demand for electricity, and convert this current into heat for the following day's space heating.

One important point for many consumers is that in some areas of the country a special cheap rate is available for current consumed during these hours. Another important point is that many factories and offices hitherto unable to employ electric heating because they were already drawing their maximum cable load during the day, will now be able to do so.

These thermal storage heaters have a maximum charging period of eight hours. Their heat output expressed as a percentage over 24 hours is 35% during the eight hour charging period, 56% during the day, and the remaining 9% in the last eight hours. The heat emitted during the charging period provides a comfortable room temperature at the start of the day.

Necessarily the heater weighs 480 lb. To overcome the difficulty of despatching and installing such a heavy mass, the heater is constructed so that it can be dismantled for transport. The heat storage medium of concrete is divided into 10 blocks each weighing 40 lb. so that they can be placed in the heater after it has been positioned and connected. Despatch is simplified by packing the heater in three sections (*a*) the metal body, (*b*) the elements, and (*c*) the concrete blocks. Full instructions for assembly are enclosed with the heater, together with lifting keys for handling the blocks.

The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

Fig. 1.—The new G.E.C. storage space heater.

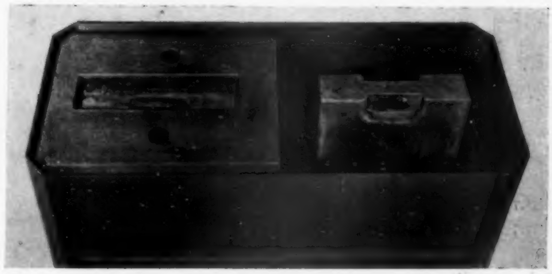


Fig. 2.—The new G.E.C. storage space heater, showing the method of mounting concrete blocks on elements embedded in concrete.

Electronic Resistance Thermometer

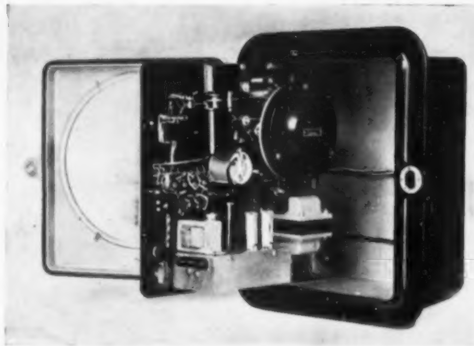
A recent addition to the range of instruments available for the measurement and control of temperature is the Fielden Electronic Resistance Bulb Multipoint Thermometer, which is suitable for use in the temperature range—200°C to +500°C. The advantages claimed for this type of equipment include: long-term high accuracy and reliability; simple design, resulting in easy, inexpensive maintenance; no galvanometers or fragile mechanisms; interchangeability of resistance bulbs to standard—without recalibration; elimination of cold-end compensation; power-operated recording mechanism; rapid pen response; and reduced thermal lag. No batteries are required for this equipment and distant indication is not restricted due to the use of capillary tubing. Other features include continuous balancing and low capital cost.

The 4-point turret pen ensures that the appropriate coloured ink, carried in separate reservoirs, is selected for each trace. The pen is positioned radially by the bridge-balancing servo-motor, and turret rotation is actuated by a plunger concentric with the rotating bush which carries the pen arm. The turret is rotated through an angle of 90° by means of a steel pawl and the pen assembly is then accurately located by a square shoulder which engages a flat spring. An important feature is that, at any time, the rotating turret mechanism may be arrested in any one of its four positions by means of a switch on the front panel. The unit then becomes a single-point continuous recorder of the temperature at the selected point.

The Sangamo-Weston resistance bulb is used as the temperature sensitive element. These bulbs cover a

range of $- 200°$ C. to $+ 500°$ C. and can be supplied in lengths of 3 in. to 36 in. Circular charts of 11 in. diameter are available to cover ranges within the limits of the resistance bulbs.

An 8-in. dial panel mounting instrument provides single or multi-point indication, and standard multi-way switches can be supplied for up to 20 measuring points, or to customer's specification.

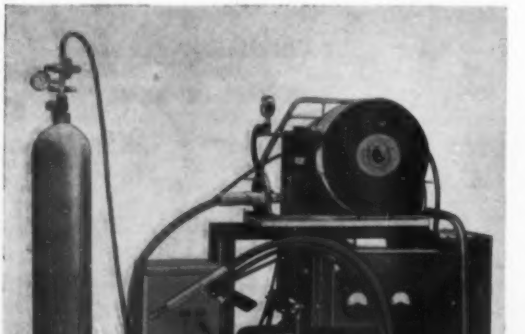


A single point recorder or recorder controller is used for continuous recording and can be supplied as a simple recorder or recorder controller. The latter incorporates cam-operated contacts for electrical on/off control in conjunction with magnetic valves, etc. A pneumatic controller is available with simple proportional control only, or with second and third term functions for more complicated processes. The ample driving power available from the servo-mechanism permits the use of an original pneumatic system which avoids the conventional nozzle and flapper technique.

Fielden (Electronics), Ltd., Wythenshawe, Manchester.

The Argonaut Welding Process

THIS is a manual argonarc welding process using the inert gas shielded arc but with a consumable electrode and automatic regulation. The Argonaut Process uses a shielded arc with direct current (electrode positive) of relatively high amperage (50,000 amp./sq. in. minimum) on a continuously fed bare wire electrode of small diameter: the high current gives a very fast deposition rate. The manner of metal transfer by projection across the arc permits welding in all positions and these last two attributes gives the process a large field of application on all types of fabrication where relatively heavy section aluminium is welded *in situ*. No flux is needed and welds are of good quality, free from slag and inclusions, and also of course from post-weld corrosion problems. With multi-pass techniques, there is no practical thickness limit and comparatively few passes are needed because of the large amount of filler metal which can be deposited in unit time. Thin metal down to $\frac{3}{16}$ in. in thickness may also be welded by using smaller diameter electrode wire and lower current.



The arc is self-adjusting and the equipment includes a reel and feed motor to supply the filler wire to the torch or gun. The feed to the gun is via a special cable which also conducts the argon gas to provide the air-excluding shield around the arc and over the weld pool. The automatic adjustment of the arc is governed by the burn-off rate of the wire which is fed at a constant speed through the gun.

To start welding, the electrode or filler wire is brought forward so that it projects about $\frac{1}{8}$ in. from the nozzle of the gun. When the trigger is pressed, the welding circuit is switched on and argon starts to flow. The tip of the wire is then brought down to the face of the joint and the arc is struck. At this stage a relay starts the wire feed motor and the wire is brought forward and the burn-off action continues. The fusion rate is very much higher than that with conventional arc welding and a higher welding speed is consequently obtained.

The use of the process is not confined to light alloys; it may also be employed on stainless steel and copper base alloys. Certain types of welds between dissimilar metals such as copper to steel can also be successfully effected employing an aluminium bronze filler wire.

From the operator's viewpoint, the Argonaut process is very easy to use in the downhand position for both fillet and butt welding, but it is in vertical and overhead welding the fillets and butts that Argonaut scores heavily, since operation in the more difficult positions is much easier than the comparative methods for normal manual arc welding. The most notable improvement is when welding in the overhead position because the effects of gravity on the weld metal crossing the arc are hardly noticeable. This allows an operator of only average welding skill to make welds in positions which otherwise would need a highly skilled operator. The main difference in technique is principally the necessity to move along the joint far more quickly than is customary with ordinary arc welding and once the technique has been mastered it is applicable to all positions and satisfactory welds result.

The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

CURRENT LITERATURE

Book Notices

IRON AND STEEL DIRECTORY

Seventh edition. 386 pp. 1953, The Louis Cassier Co., Ltd., London. 25s. (postage 8d.).

THE section of the Directory which forms a useful guide to those interested in obtaining iron and steel castings, pig iron and steel, includes a completely revised list of British pig iron manufacturers, and detailed lists of some 2,500 iron founders, steel founders, steel works, etc., arranged geographically and alphabetically. Other details listed include those of the British iron and steel groups and their subsidiaries, trade associations and scientific and technical societies.

This volume also contains a large amount of technical data for engineers, metallurgists and iron and steel makers and users. This includes typical compositions for various grades of iron, steel and ferro-alloys, abstracts of British specifications for ferrous materials (including the aircraft and D.T.D. series), and a number of useful conversion tables.

The final section comprises a classified list of manufacturers engaged in the iron, steel and allied trades, together with a list of their addresses. Some 385 products are listed, ranging from abrasive wheels to X-ray films, and including such items as foundry bonding materials, furnaces, refractories, steel plates, strip and wire, tube-making plant, etc.

ANTIMONY

ITS GEOLOGY, METALLURGY, INDUSTRIAL USES AND ECONOMICS

By C. Y. Wang. Third Edition Revised. 170 pp. including appendix and index. London, 1952. Charles Griffin & Co., Ltd. 25s. net.

THE third edition of this authoritative book has been long awaited by both the student and those concerned with winning antimony from its ores. The original structure has been generally adhered to, though the chapters on history, chemistry, mineralogy and analysis have been omitted from this edition.

The book opens with the chapter on geology giving a very complete picture of the distribution and nature of the world's known ore deposits. There follows the chapter on the extraction and refining of the metal. Pyro-metallurgical, hydro-metallurgical and electro-metallurgical methods are reviewed in that order and the chapter is concluded with a section on ore dressing. The plant details, operation technique and chemistry of the various processes are competently treated. After dealing with the more conventional methods, the author devotes a section to the more recently developed special processes. Of particular interest is the reference to the adoption of a rotary furnace at the Herzog-Julius Smelter in Germany for smelting high grade concentrate. The author himself was partly responsible for the development of another such process, the Hodson-Wang, which is described in some detail in the appendix. This process is unique in that fairly pure antimony is extracted from either oxide or sulphide ore in one continuous operation, and that waste heat from the reduction stage is utilised in providing heat for the rest of the process.

The problem of dust and fume collection is dealt with rather sketchily. Reference is made to the adoption of the Venturi scrubber but with no mention of efficiency and running costs compared with the more conventional filtration or precipitation methods.

The section on hydro-metallurgical methods is brief and of academic interest only. Similarly, that on electro-metallurgical methods is mainly concerned with the researches of various workers on the subject. Reference is made, however, to a full scale plant in operation at the Bunker Hill Mining and Concentrating Co., Idaho, for the production of antimony from tetrahedrite concentrates.

In the third chapter, the author reviews the industrial uses of both the metal and its compounds. The fourth and final chapter is devoted to economics and is mainly concerned with world production and consumption statistics.

Dr. Wang has presented this monograph in a clear, concise and readable style. Many of the descriptions of the various processes are accompanied by drawings of the plant used which are complete without being obscured by a mass of minor constructional detail. The chapters on geology and metallurgy include bibliographies supplementing those which have appeared in the two previous editions.

J. D. ABLETT.

Trade Publications

AN interesting and well illustrated booklet has been issued recently by Davy and United Engineering Co. Ltd., on the subject of shears for hot and cold metal. A large section of this publication deals with hot bloom and slab shears, reference being made to the requirements of design, the type of shears available, the method of drive, the frame design, the layout in relation to the mill and the arrangements for removing and handling the crop ends. Other sections deal with hot and cold billet and bar shears, Morgan electric flying billet shears and plate shears, including rotary side trimmers, etc.

A BUYERS GUIDE, issued by International Meehanite Metal Co. Ltd., 66, Victoria Street, London, S.W.1, lists all the foundries licensed to operate the Meehanite metal process both in this country and overseas. Meehanite Metal is a series of high-duty cast irons produced by the Meehanite system, the whole series meeting the needs of the engineers, not only in general engineering applications, but also in such specialised fields as heat, wear and corrosion resistance.

" PLUMBAGO in the Service of the Metal Industry " is the title of a booklet recently issued by The Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W.11. Salamander material is noted for its durability, thermal conductivity, elasticity, and resistance to attack by fuel, slags and fluxes, and the products described in the pages of this booklet indicate the extent to which these properties are utilised to serve the metal industry. Crucibles for all types of melting furnaces are featured in the largest section of the book, but other applications range from zinc distillation retorts to knock-off riser plates, and from brazing pans to stoppers and nozzles.

An illustrated folder recently issued by Electronic Instruments, Ltd., Red Lion Street, Richmond, Surrey, describes the full range of standard laboratory and industrial measuring instruments made by the Company. In the *p*H measurement field, reference is made to laboratory and industrial electrodes and to a portable *p*H meter, a direct reading *p*H meter and an industrial *p*H transmitter.

The Industrial Diamond Trade Names Index was first published as an 8-page data sheet in 1945 containing some 200 names and addresses. It has now been thoroughly revised, making use of many sources of information in this country and abroad, and the 1953 edition contains approximately 1,000 trade names of manufacturers of diamond tools, abrasives, etc. Copies may be obtained from Industrial Distributors (Sales) Ltd., Industrial Diamond Information Bureau, 32–34, Holborn Viaduct, London, E.C.1.

The new "Materials and Fabrication" booklet issued by T.I. Aluminiun, Ltd., Redfern Road, Tyseley, Birmingham, 11, gives details of the composition and mechanical properties of the Company's range of aluminium alloys. Different classes of product—sheet and strip, bars and sections, tubes and plate—are segregated and particulars are given of the specifications met in each case. Information is also given on the heat treatment, machining, forming, joining and surface finishing of the alloys. This is the first of a series of brochures; later publications in the series will deal with specialised applications in various fields of industry and show how the specific features of these materials can be used to best advantage.

A recently issued leaflet of The Morgan Crucible Co. Ltd., Battersea Church Road, London, S.W.11, concerns M.R. Plastic Mouldable, which is a super-duty refractory compound of a stiff malleable consistency, supplied ready for use. It has a 60% alumina content and is recommended for service at high temperatures or where severe spalling or slagging is encountered. The maximum operating temperature of 1,650° C. makes it suitable for use in the majority of industrial furnaces.

A brief description of some of the products developed by the Company to provide accurate electrical control in many processes is given in a leaflet issued by Sunvic Controls, Ltd., 132/135, Long Acre, London, W.C.2. They include a cold junction thermostat, creep test control panels, a D.C. amplifier, electronic relays, energy regulators, vacuum pumping equipment, hotwire vacuum switches and relays, resistance thermometers and controllers, thermostats, time delay switches, a toluene regulator head and a high-speed recorder.

Elcontrol, Ltd., have recently issued two new data sheets. No. 4 (issue 3) deals rather more extensively with electronic process and cyclic timers than did the previous issue: in addition a new cyclic interval switch (type C.S.3) is described. This model embodies the conventional two relays and can, therefore, be used for controlling two separate circuits if required. Data Sheet No. 8 describes and illustrates a standard production type of photo-electric pyrometer controller of the on-off type. This instrument is likely to be of interest in resistance butt-welding and the heat treatment of metals.

We have received from F. J. Edwards Ltd., 359–361, Euston Road, London, N.W.1, Stock List SL153 which lists the new and second-hand sheet metal working machine tools, wood-working and tin box machines, presses, etc., to be seen at the F.J.E. Machine Centre, Islington Park Street, London N.1.

Among the copper alloys used in engineering, there are few which have such useful properties as the copper-aluminium alloys, known as "Aluminium Bronze." In a useful pamphlet issued recently by Fry's Diecastings, Ltd., Brierley Hill Road, Wordsley, Nr. Stourbridge, the properties of aluminium bronze diecastings are detailed. As with other alloys, the chilling effect in diecasting results in superior properties to those of sand castings. Besides the normal mechanical properties, reference is made to corrosion resistance, finishing, joining and machining, whilst a further section deals with considerations of design.

We have received from Monometer Manufacturing Co., Ltd., a new brochure on oil and gas-fired hot metal receivers for use in the ironfoundry. The purpose of these receivers, which are fed from the cupolas and maintained pouring at temperature, is to ensure a really hot slag-free metal being available at all times to suit the capacity of the foundry. The capacities range from 1 to 10 tons, the oil consumption varying from 5 gal./hr. for small receivers up to 15 gal./hr. for 10-ton receivers. The high-grade silica brick lining is suitably insulated and lasts up to 9 months. Copies of the brochure may be obtained from Savoy House, 115–116, Strand, London, W.C.2.

Books Received

"Qualitative Analysis and Analytical Chemical Separations." By Philip W. West, Maurice M. Vick and Arthur L. Le Rosen. 223 pp. including appendix and index. New York, 1953. The Macmillan Company. $3·75.

"The Physical Chemistry of Melts." A Symposium on the Nature of Molten Slags and Salts held by the Nuffield Research Group in Extraction Metallurgy, London, 20th February, 1952. 106 pp. London, 1953. Institution of Mining and Metallurgy. 15s. (7s. 6d. to I.M.M. members.)

"The Physical Chemistry of Copper Smelting." By R. M. Ruddle. 156 pp. including subject and author indices. London, 1953. Institution of Mining and Metallurgy. 20s. (10s. to I.M.M. members.)

"A Handbook of Colorimetric Chemical Analytical Methods for Industrial, Research and Clinical Laboratories, developed for use with the Lovibond Comparator." 120 pp. Salisbury, 1953. The Tintometer Ltd. 15s. By post 15s. 6d.

"Iron and Steel Directory." Seventh Edition. 386 pp. London, 1953. The Louis Cassier Co. Ltd. 25s. By post 25s. 8d.

"Fatigue of Metals." By R. Cazaud. Translated by A. J. Fenner. With a foreword by H. J. Gough. 334 pp. including author and subject indices and numerous illustrations. London, 1953. Chapman and Hall, Ltd. 60s. net.

"Proceedings of the Institute of British Foundrymen." Vol. XLV. 1952. Containing the Papers presented to the Forty-ninth Annual General Meeting and a selection of Papers presented to Branch Meetings during the Session 1951–52. Edited by G. Lambert. Manchester, 1953. Institute of British Foundrymen.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

MAY, 1953 Vol. XLVII, No. 283

Arc-Melting of Non-Metallic Materials and a Re-Determination of the Beryllia-Thoria System

G. A. Geach,* M.Sc., Ph.D., F.I.M., and M. E. Harper†

To illustrate the use of the arc furnace, with inert gas atmosphere and water-cooled copper hearth, for the melting of non-metallic materials, the behaviour of several of these is reported together with its application to a study of the beryllia-thoria system.

A type of furnace in which heating in an inert atmosphere is by an arc between one inert electrode and a specimen was first described by R. Hare[1], who used it to bring about reaction between inorganic materials. A similar arc-furnace was later used by W. von Bolton[2] for melting tantalum. Recently, such furnaces have been much used in work with reactive high-melting-point metals, for not only can all of these be melted, but no containing crucible of refractory material is required (*cf.* descriptions by W. Kroll[3] and G. A. Geach and D. Summers-Smith.[4])

In the course of work with such furnaces we have found it possible to heat and melt not only metals, but also a very wide range of refractory inorganic materials. As it is also possible to make rough measurements of melting points, the general form of the melting-point diagrams of refractory systems may be very easily obtained.

Arc-furnaces of this type consist in general of a water-cooled hearth which carries the specimen, and a movable electrode, usually of tungsten, the whole being enclosed in a vessel containing the protective atmosphere. The atmosphere is commonly argon at a pressure of about 20 cm.Hg. This gas is purified by passing over magnesium at 600° C. before entering the furnace and then further by arc-melting and heating in it a piece of zirconium. The latter may then be pushed aside and replaced by a specimen, or by a series of specimens in their turn, without opening the furnace vessel and using the electrode as a tool. Power for the arc is usually drawn from a welding generator.

A few grams of the material to be melted, in the form of one compact piece or of a pressing made from powder, are placed in the centre of the hearth and an arc struck by lightly touching the hearth with the electrode. It is essential in striking an arc in this manner to use a low power setting (1 kW). If a high power setting (3 kW) were used, the initial power surge would be capable of puncturing the hearth.

* Physical Metallurgy Section Leader, Associated Electrical Industries Research Laboratory, Aldermaston, Berkshire.
† Technical Assistant, Associated Electrical Industries Research Laboratory Aldermaston, Berkshire.

As soon as the arc has become stable, the electrode is so moved that the arc forms an envelope about the specimen which is thereby heated until, at a temperature usually between half and three-quarters of its melting point, it commences to conduct the arc current. When different materials are melted together, convection stirring ensures a homogeneous mixture. Contact between the refractory and the copper hearth should be good, as otherwise secondary arcing between the specimen and hearth may lead to pick-up of copper.

The Melting of Non-Metallic Materials

To illustrate the use of arc-furnaces for melting non-metallic materials, the behaviour of several of these is reported. Unless stated otherwise, the melting-points given are taken from the Handbook of Chemistry and Physics, 33rd Edition, 1951–1952.

Silicon (M.P. 1,420° C.)

This melted without difficulty. It froze to dark blue-grey, metallic-looking beads, which had conical points at the last part to solidify (probably due to expansion on solidification). Attempts to melt silicon in an arc-furnace using sintered silicon as the upper electrode have been mentioned by W. R. Johnson, B. Karminsky and M. Hansen.[5] These failed as the silicon electrode became hot and melted the metal clamp holding it.

Aluminium Oxide (M.P. 2,050° C.)

Small rods of re-crystallised alumina melted without difficulty to a grey glass bead. X-ray powder photographs taken with copper-Kα radiation showed no change to have occured in the structure of the material used.

Beryllium Oxide (M.P. 2,570° C.)

A pressed pellet of beryllia melted to form a very hard, white, crystalline mass. The liquid was fairly viscous and a smooth round bead was not obtained. No change in structure was detected by X-ray diffraction.

Calcium Oxide (M.P. 2,572° C.)

Heated to ensure the absence of water before being put into the arc-furnace, this material then melted in the

Top Row (left to right): Iron oxide, thoria, titania, tantalum oxide, chromium oxide.

Bottom Row (left to right): 30% beryllia/thoria, beryllia, calcium fluoride, sodium fluoride alumina.

Fig. 1.—Arc-melted specimens. $\times 1\frac{1}{4}$

arc to form a pale yellow, translucent mass. The rate of reaction of the fused material with either water or 25% hydrochloric acid was small; attack by cold water was not apparent in two hours, but was appreciable after 24 hours. X-ray photographs showed a cubic calcium oxide structure. Analysis showed the material to contain 71·7% calcium.

Chromium Oxide (*M.P.* 1,990° *C.*)

Laboratory grade chromium oxide melted, giving off a large amount of vapour. In its liquid state this compound became a very good electrical conductor; it resembled water in its fluidity. The solid after fusion was a bright black, crystalline mass. X-ray diffraction showed only the chromium oxide structure.

Iron Oxide (*M.P. approximately* 1,500° *C.*)

The oxide, prepared by heating ferrous hydroxide at 900° C. in air, melted into a black bead having magnetic properties.

Magnesium Oxide (*M.P.* 2,500° *C. to* 2,800° *C.*)

'AnalaR' magnesium oxide could not be melted owing to the extremely high rate of its vaporisation.

Silica (*M.P.* 1,600° *C.*)

Clear silica melted, but only with considerable difficulty due, apparently, to rapid vaporisation of the solid and poor electrical conductivity in the liquid state.

Tantalum Oxide (*M.P.* 1,470° *C.*)

Tantalum oxide melted easily to a fluid mass having good electrical conductivity. The black crystalline bead obtained when this solidified still possessed good electrical conductivity; (the resistance was of the order of 50 ohms across a bead 1 cm. in diameter). The normal high resistivity of the material was restored by heating the fused bead in air at 1,000° C. for one hour. The colour throughout the bead then changed to a light grey-green. X-ray investigation on the fused materials revealed a change in structure from that of the original material. However, the structure of the fused material after heating in air was almost completely restored to its original form.

Thorium Oxide (*M.P.* 3,030° *C.*)[6]

Thorium oxide powder melted; it froze to a glossy black solid. X-ray diffraction showed no change in structure.

Titanium Dioxide (*M.P.* 1,840 ± 10° *C.*)[7]

Titanium dioxide melted to a very mobile liquid of good electrical conductivity and low viscosity. The melting of sintered titanium dioxide in an arc-furnace has been reported by A. E. Jenkins[8] since our work was completed.

The blue-black, crystalline bead formed on solidifying still exhibited good electrical properties, (the resistance across a bead 1 cm. in diameter was approximately 20 ohms). When the fused bead was heated in air for one hour at 1,000° C., the colour on the outside changed to a light grey but on freshly fractured surfaces it remained blue-black in colour. The resistivity rose to values of the normal order after this heating.

X-ray powder diffraction photographs showed the original material to be brookite, but after fusion and also after the further heating at 1,000° C. only the pattern of rutile was obtained.

Vanadium Pentoxide (*M.P.* 690° *C.*)

Laboratory quality vanadium pentoxide melted easily to a liquid of low viscosity. X-ray diffraction showed a change in structure to occur on melting.

Glass.

A rod of B.T.H. C.9 glass was melted and boiled with ease.

Porcelain.

This melted without difficulty forming beads which were very viscous in the liquid state. The solidified material was transparent.

Calcium Fluoride (*M.P.* 1,360° *C.*)

A pressed pellet of precipitated calcium fluoride melted to form a smooth, matt-grey bead. No change was found in the structure of the material.

Sodium Fluoride (*M.P.* 980 *to* 997° *C.*)

Sodium fluoride melted easily and solidified to a light grey crystalline solid. X-ray diffraction showed no change in the structure to occur.

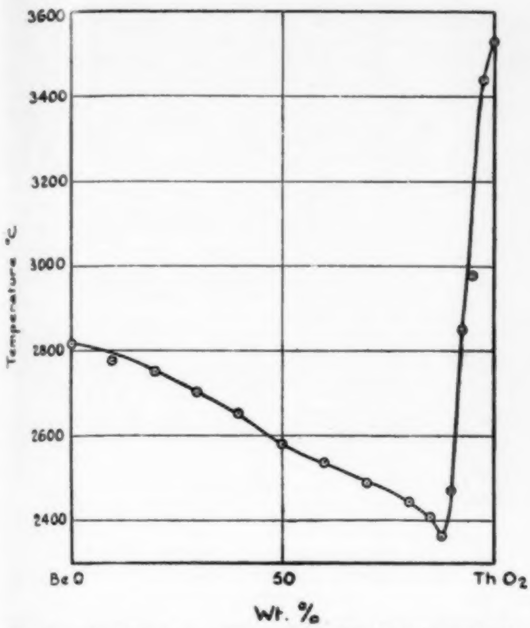


Fig. 2.—Liquidus curve for the beryllia/thoria system.

Calcium Carbide (*M.P.* 2,300° *C.*)

Commercial calcium carbide was melted. Rapid vaporisation accompanied melting, necessitating a high rate of heating. The product was a chocolate-coloured mass. No change in structure was shown by X-ray diffraction photographs.

The Beryllia-Thoria System

A re-examination of the system beryllium-oxide/thorium-oxide has been made by melting-point determinations. Small beads of compositions spread across the system were prepared by arc-melting pressed pellets of mixed powders.

Melting points were estimated using a disappearing-filament pyrometer which was sighted on the boundary between liquid and solid on the surface of a bead, which was held partially melted by suitable control of the power in the arc. A correction-curve was obtained by observations made in a similar way on refractory metals of known melting-points.

Temperatures obtained in this way do not accurately represent true melting points, but values obtained give the form of the liquidus curve, a result which is of primary importance. The melting points of metals are, it is believed, measured with an accuracy of $\pm 50°$ C., but the uncertainty with oxides is probably greater and has not been so well established. A value of 3,530° C. was obtained for the melting point of thoria. S. Tacvarian[9] obtained a value of 3,030° C. and F. P. Hall and H. Insly[10] gave a value of approximately 3,060° C.

The liquidus curve obtained (Fig. 2) shows a eutectic between 10 and 15 wt. % beryllia having a melting point of approximately 2,360° C. F. P. Hall and H. Insly[10] and H. Wartenburg, H. I. Reusch and E. Saram[11] give a eutectic at about 20 wt. % beryllia having a melting point of approximately 2,200° C.

All the mixtures of these oxides were good electrical conductors in the liquid state, and all except those thoria-rich compositions with less than 15% beryllia gave white crystalline solids; the thoria-rich samples varied in colour from light grey to the glossy black colour of pure thoria. X-ray diffraction photographs showed no intermediate compounds. The thoria pattern was dominant in all photographs, but the beryllia pattern was detected in mixtures with 50% beryllia and more.

The system magnesium-oxide/vanadium-pentoxide proved unsuited to study by this technique because vaporisation of both oxides in the furnace was so great that consistent melting-point determinations could not be made.

Acknowledgments

The authors wish to express their appreciation to Dr. T. E. Allibone, F.R.S., for permission to publish this paper.

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Conference on Non-Destructive Testing of Steel Castings

ON April 22nd Members of the British Steel Castings Research Association from all parts of the United Kingdom attended a One-Day Conference on Non-Destructive Testing, held at the Engineering Centre, Sauchiehall Street, Glasgow. DR. R. HUNTER, Joint Managing Director of the Clyde Alloy Steel Co., Ltd., was in the Chair, and some 75 persons were present.

The purpose of this B.S.C.R.A. Conference was to present to its Members the results of the Research Association's development work related to radiography, and to radiological scanning in particular, and to consider the present and future application both of ultrasonic testing and of zero-radiography in relation to steel castings quality control. Papers, accompanied by demonstrations in each case, were presented by MR. G. T. HARRIS, M.A. F.Inst.P., (Research Manager, William Jessop & Sons Ltd. and Chairman, B.S.C.R.A. Non-Destructive Testing Panel), by MR. W. D. OLIPHANT, B.Sc., M.I.E.E., F.Inst.P. (Ferranti Ltd.) and by MR. G. M. MICHIE, M.A., A.Inst.P., A.I.M. (Chief Physicist, British Steel Castings Research Association).

Also organised by the B.S.C.R.A., in conjunction with the manufacturers, was an Exhibition of the latest ultrasonic testing equipment held in the Engineering Centre. This Exhibition was opened to the public immediately after the Conference and the next day.

Change of Address

THE commercial groups of Mullard's Equipment Division have moved to 6, Gate Street, Lincoln's Inn Fields. The General Manager of the Division, Mr. J. P. Jeffcock, and his immediate staff remain at the Company's Head Office at Century House, Shaftesbury Avenue, London, W.C.2, and all correspondence should continue to be addressed to Century House. The commercial activities of the three product groups—radio, telephone and general electronics—will be centralised at Gate Street, under the Commercial Manager, Capt. R. T. Paul. The telephone number is Chancery 8421 or Gerrard 7777.

The metallography and physical metallurgy laboratory.

Nottingham University Engineering Laboratories

New Extensions Increase Intake of Applied Science Students

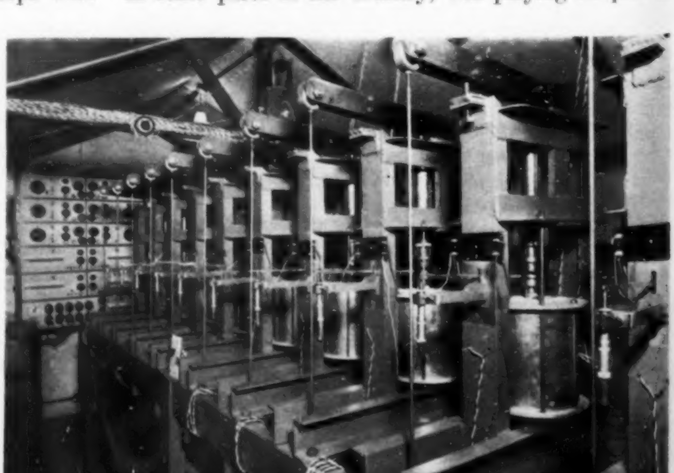
THE new extensions to the civil and mechanical engineering laboratories of the University of Nottingham, which were opened by Lord Hives, Chairman of Rolls Royce, Ltd., on April 14th, represent a compromise solution to the problem of finding accommodation for the increased number of students in this section of the Faculty of Applied Science. The original drawing offices and laboratories were completed in 1930, at a time when the number of full-time students in civil, mechanical and electrical engineering was less than 20. The numbers had risen to 44 by 1940, and to 128 by 1946, whilst in 1950 there were some 200 reading for degrees in engineering. These numbers were, of course, inflated by the number of ex-servicemen taking courses, but there was an obviously increased normal demand for training which could only be met with existing accommodation and facilities by splitting each year into two main streams. Such conditions are obviously unlikely to be conducive to efficient training, and steps were accordingly taken to remedy this unsatisfactory state of affairs.

Of the two projects considered, one was for a large building project which would have taken about six years to complete, and which would have reduced the intake of students during that period. The short-term project, which was finally adopted, was completed in a little over two years, and during that time the number of students was maintained at the 1950 level and active research schools were developed. In describing the extensions, Professor J. A. Pope, Head of the Civil and Mechanical Engineering Department stated that adoption of the short-term project had not shelved the larger scheme but merely delayed it slightly.

The extensions represent an increase of some 60% in the available accommodation, and when the rooms at present loaned to the Faculty of Arts are freed, the total increase will be 80%. This has brought the facilities for civil and mechanical engineering training in line with those for electrical and mining engineering, and has enabled a sub-department of metallurgy to be established. The annual intake of students has been fixed at 20 each in civil, mechanical, mining and electrical engineering, and 10 in metallurgy.

Demand for Technologists

In his address at the opening ceremony, Lord Hives stressed the importance of the applied scientist, on whose efforts the country was becoming increasingly dependent. It was very disturbing to note that, in 1950–51, of the 72·5% of students in receipt of some form of State aid, only 12·4% were studying technology, and he, therefore, welcomed the action of the University of Nottingham in anticipating the increase in the facilities required for training. The Government too, by the establishment of a University of Technology, and by making available resources for extending facilities in other parts of the country, was playing its part in



The creep testing laboratory.

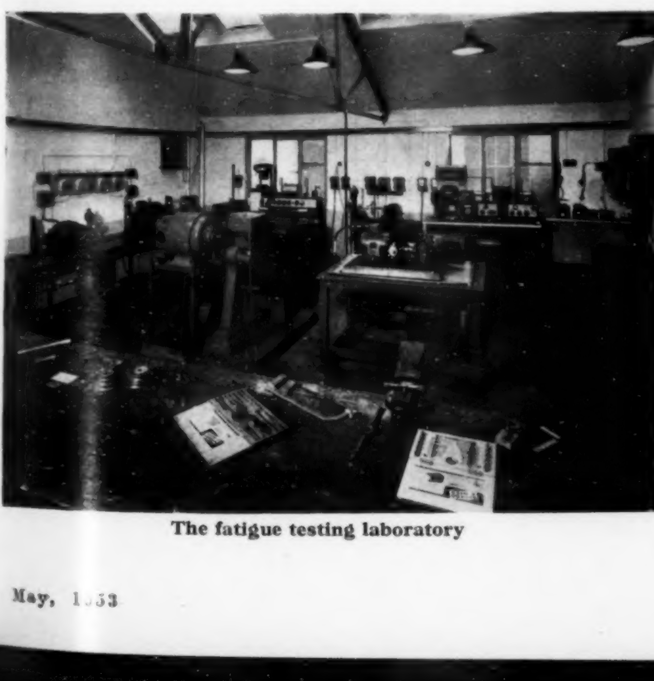
attempting to meet the demand for trained technologists. Valuable as such steps were, Lord Hives felt that the cause of the low figure quoted did not lie in the facilities available at university level. It had a much deeper root, he continued, for it rested in the attitude of mind of the parents and of the schools, for there still survived the idea that a career in industry was not so respectable as one in the services or the professions. Such an attitude was not only out of date, but was definitely harmful if Britain were to remain a great power. We were constantly being exhorted to study the American approach to industrial problems, and whilst he did not feel we should copy American industrial training methods, Lord Hives said we should certainly reflect upon the high position in society which the Americans gave to industry and by which it attracted the best brains. In view of the situation he had described, it was particularly interesting and encouraging to note that a large number of schoolmasters from all over the country had been invited to see the new facilities.

The furnace room.

The New Buildings

The construction of the new buildings is utilitarian and every effort has been made to cut down cost, principal stress having been laid on the provision of first-class equipment. An interesting feature, which has been largely responsible for saving space, is the use of convertible wooden furniture which has enabled a single room to serve as lecture theatre, drawing office and, for certain purposes, laboratory. Alternate forms of this prototype furniture, which has been designed by the staff, have hinged tops which for normal lecture purposes form the writing table for those seated behind. When the room is required as a drawing office, the hinged top is swung over to form a solid table with the fixed top of the form in front. Additionally, each form incorporates adequate locker space.

During the past few years great progress has been made in the Applied Science Laboratories. Not only has laboratory space been almost doubled, but, by the generous assistance of both the University Grants Committee and industry, a considerable quantity of new equipment has been installed in the laboratories. These laboratories have been designed and developed to fulfil the dual function of teaching and research in almost every branch of engineering science. The central feature of this recent development has been the equipping of modern workshops, staffed with highly-skilled craftsmen, which have already proved a most valuable asset, since the apparatus required for laboratories, lecture demonstrations and research can now be made within the department.



The fatigue testing laboratory

Degree Course in Metallurgy

To date, metallurgy has been a subsidiary subject for engineering students, but a degree course in metallurgy is now about to be introduced. The peculiarly metallurgical laboratories include a metallographic and physical metallurgy laboratory and a well-appointed furnace room. The former is equipped with a Vickers projection microscope, several bench microscopes, micro-hardness testing equipment, and apparatus for determining various physical properties of metals at room and elevated temperatures. A separate room is provided for the preparation and etching of specimens for metallographic examination. Heat-treatment equipment available includes two Birlec controlled atmosphere furnaces, one with a rating of 16kW and 1,000° C. maximum temperature, and the other with a 20kW rating and a maximum temperature of 1,400° C.; a Birlec 8kW forced air circulation tempering furnace; an I.C.I. gas-fired salt bath; and an I.C.I. ammonia cracker. For isothermal treatment, low temperature salt baths with a maximum operating temperature of 650°C. are available. Melting facilities include Efco high-frequency equipment for 15–20 lb. melts of steel and a Morgan gas-fired crucible furnace.

The study of the mechanical properties of metals forms an important part of any metallurgy course, and for the practical

work in this subject use will be made of the materials and structures laboratories of the engineering departments. Several machines are available for tensile and compression testing of materials, a notable example being the 500-ton capacity strut testing machine. Included in the available hardness testing machines are the Brinell, Vickers, Firth and Rockwell types, whilst provision is also made for determining the impact and drawing properties of various metals and alloys.

Although metallurgy has been only a subsidiary subject, a number of researches in progress are of metallurgical interest. These include studies of the creep properties of cast iron, plastic deformation of metals, effect of surface stressing on the fatigue life of metals, plastic collapse of steel structures, high-speed fatigue testing of coil springs, and the dynamic, tensile and torsional properties of different metals.

Entrance Requirements

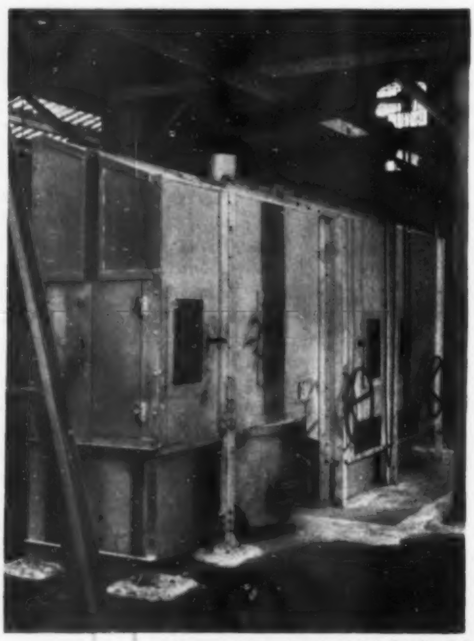
Students may be admitted to the degree course in metallurgy direct from school with a General Certificate of Education at ordinary level in English language, mathematics, a foreign language and one other subject, and at advanced level in chemistry, physics and mathematics (optional). Such students are admitted to the first post-intermediate year of the course and proceed to a degree in three years, Part I examinations being at the end of the second year and Final examinations at the end of the third.

Students who have matriculated, but who have not studied physics and chemistry to the advanced level of the General Certificate of Education are not admitted directly into the Applied Science School, but must spend an "Intermediate Year" studying physics, chemistry and mathematics. Similarly, students who wish to enter from industry at 21 must first pass a special entrance examination and then, starting with an "Intermediate Year," proceed to a degree in four years. The University has under consideration the entrance requirements for students who enter industry on leaving school at 16 years of age with a General Certificate of Education at ordinary level, but who at the age of 18 or 19 wish to study applied science at a university. Such students would normally read four years for a degree. It is anticipated that the precise entrance requirements for such candidates will be available before the commencement of the 1953/4 session.

Heat-Treatment Furnace Developments

continued from page 262.

in the closely spaced electrode-type salt bath, such as the Efco-Ajax-Hultgren salt bath. In this type, one or more pairs of electrodes are immersed in the salt, which, in the molten state, is a conductor of electricity. Each pair is closely spaced, and when an electric current flows through the molten salt in the gap between the electrodes, it becomes heated by direct resistance. Operating voltages are so low that there is no danger of electric shock should any metallic part be touched inadvertently. The pairs of electrodes are arranged in close proximity along one side of the bath so that a clear working space is available. The patented grouping and design of the electrodes produces a strong circulation of the salt by the electro-magnetic force generated round each pair of electrodes, and uniform temperature distribution is assured, regardless of the size of pot used.



Courtesy of Imperial Chemical Industries, Ltd.

Fig. 43.—A totally enclosed salt bath plant for cyanide hardening small work in baskets. This plant incorporates a preheater, salt bath and water and oil-quenching tanks.

Acknowledgement

Owing to pressure of work in other directions, a number of well-known builders of heat-treatment plant have been unable to supply us with details of their developments and, in consequence, this article is not quite so comprehensive as we would have wished. We are, however, greatly indebted to those firms who have supplied information and photographs, and we would express our grateful appreciation to them, and to the firms in whose works the various items of plant are installed, for permission to publish the details and illustrations.

Pease Anthony Scrubbers

THE POWER-GAS CORPORATION, LTD., who are the licensees for the Pease Anthony Scrubbers, now have a pilot plant unit available for experimental purposes on a variety of applications. The unit, which is mobile, can handle 500 cubic feet of gas per minute and is capable of dealing with micron and sub-micron dusts and fumes.

Change of Address

BRITISH Insulated Callender's Cables, Ltd., announce that with effect from Monday, May 4th, 1953, their Lincoln Branch Office is transferred to 113 Canwick Road. The telephone number remains unchanged at Lincoln 654.

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